REPORT

ON THE

WATER SUPPLY

OF

PLAINFIELD

NEW JERSEY

JAMES H. FUERTES
CONSULTING ENGINEER
NEW YORK

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Report on Plainfield's Water Supply.

PART I.

New York, November 21st, 1910.

To The Common Council of the City of Plainfield, N. J.

Gentlemen:—

In pursuance of instructions received from your special Water Committee, I have investigated the available sources of water supply for Plainfield, and herewith present my report thereon.

During the progress of the work the benefit of frequent conferences with members of your Committee and other officials of Plainfield has been extended to me, and it is a pleasure to record here my appreciation of the assistance derived from this friendly cooperation. I wish especially to acknowledge my indebtedness to Mr. Andrew J. Gavett, C. E., City Engineer and Street Commissioner, for much data and information regarding local conditions.

During the progress of the investigations I nave gone over the entire field personally, have visited all the proposed sources of supply, examined local conditions, conducted such surveys as were necessary to establish with accuracy relative elevations of critical points, have studied the geological conditions on the ground, have visited many of the supplies of water in that locality and have collected and analyzed many samples of the different waters. In the following pages the general and most important results and conclusions are set forth at some length. For convenience a brief summary of some of the more important facts is here stated:

1. The estimated population of Plainfield is 22,000; by 1940 this is likely to increase to 55,000.

2. The present consumption of water in Plainfield is about 2,000,000 gallons daily, or a little over 90 gallons per capita, based on the quantities of water reported as pumped at the Netherwood station; corrected for errors in the measurement of the water the consumption is probably more nearly about 80 gallons per capita daily. I have assumed, in making up the estimates that the consumption is now actually about 85 gallons per capita daily and that this rate will increase to 100 gallons per capita by 1940, by which time the average total daily supply required will be 5,500,000 gallons.

3. The maximum rate of consumption for short periods, on occasional days, may reach twice the average rate and during large conflagrations three times the average daily rate.

4. Plainfield is supplied with ground water from the Netherwood pumping station of the Plainfield-Union Water

Company. Water from this station is also pumped to Fanwood, Westfield, Cranford, Roselle and Elizabeth; and during the past summer the supply for a short while could be kept up only with help from the Robinson's Branch Pumping Station, located south of Westfield.

5. The constantly increasing draft on the wells, at the Netherwood station, has lowered the ground water at the plant to about the lowest limit permissible, and the present rate of draft can not be maintained indefinitely; an additional supply from somewhere is, therefore, imperative. The Water Company has, as one expedient, drilled several new wells deep into the underlying shale rock at the site of the old wells and has thus secured a supply of extra water; how much can be permanently secured from the wells is unknown at present. Their yield does not, it is said, reduce the yield of the old wells.

6. The Netherwood works at present (the new wells are not yet in service) have not sufficient reserve capacity to render the service that Plainfield is entitled to. There is no storage, worthy the name, in the system, and if a serious fire had occurred in Plainfield during the period of shortage in July last, the Company could not have furnished water fast enough to have afforded effective fire protection. There were times during that period when the stand pipe could not be filled, because the wells, even with the help of what could be taken from the already spare supply at the Robinson's Branch Station, could not yield water fast enough to allow the pumps to force into the mains as much water as was being drawn out by the consumers.

7. The contemplated extensions, if the expectations of the Water Company are realized as to yield, combined with the available yield of the original wells, would be just about sufficient to take care of Plainfield's consumption for the next 25 or 30 years, providing no water were pumped to the east, and providing a distribution reservoir holding about one day's supply were built, on the hills back of Plainfield, to furnish a reserve for extraordinary rates of consumption and for fire protection.

8. I find that the water in the gravel deposits and the water in the shale rock underlying Plainfield have different origins, come from different gathering grounds and are at different pressures; in other words, they are separate and distinct sources of supply, and taking water from one does not affect the other. I also find that the water from deep down in the shale rock underneath Plainfield shows, by its purity and freedom from organisms that it receives no pollution from the city's wastes or sewers and is safe from a sanitary point of view; that there is a sufficient supply for Plainfield and that the continuance of the Netherwood plant in the hands of an independent company would not interfere with the supply which Plainfield could acquire at its own plant.

9. I find that it would be impracticable for the City of Plainfield to acquire or purchase the Netherwood wells and pumping station, for the reason that the sum necessary to compensate the Plainfield-Union Water Company for its franchises and for breaking its contracts with other munici-

palities, which it supplies from the Netherwood sources, added to the value of the physical plant, would far exceed the sum for which Plainfield could secure an equally good supply from other sources.

10. I find that the City of Plainfield could, if it desired, secure a gravity supply of water from either one of two sources, or a pumped supply from either of three sources, the waters in each case to be clear, pure and soft, the costs for construction not beyond the means of the city, and the annual cost for operation not greater than would be amply taken care of by the rates now in force.

11. The street mains in Plainfield are in good condition and the system is well laid out and proportioned. I estimate that, with all appurtenances, the street mains could be reproduced at present prices for labor and materials for $286,500.00, and that the measure of the depreciation of the present mains is a little under $39,000.00, based on an assumed life of 80 years for the cast iron pipe and about 40 years for the valves and hydrants.

12. I find that the city could, if it so desired, build a new set of street mains, leaving the existing mains in the possession of the Water Company; or could afford to pay the Water Company for its mains, if it chose to sell them to the city, the sum for which the mains could be rebuilt anew.

13. I find that the cost of construction and operation of the various possible plants would be as follows:

Supply.	Costs of Construction. Capacity of Works. Gallons daily.		Annual Costs of Operation. Capacity of Works. Gallons daily.			
	4,000,000	8,000,000	4,000,000		8,000,000	
			A.	B.	A.	B.
A. Filtered gravity supply — Lamington River	$1,161,000	$1,374,000	$80,000	5.5	$94,000	3.2
B. Filtered gravity supply — North Branch of Raritan River	1,325,000	1,531,000	91,000	6.2	106,000	3.6
C. Filtered pumped supply — North Branch of Raritan River	1,009,000	1,177,000	93,000	6.4	134,000	4.6
D. Filtered pumped supply from the Passaic River	805,000	973,000	81,000	5.5	116,000	4.0
E. New deep-well supply if soft water is yielded by wells	714,000	962,000	67,000	4.5	100,000	3.4
F. New deep-well supply if hard water requiring softening, is yielded by the wells	841,000	1,113,000	87,000	5.9	133,000	4.5

Note—In Columns A. and B. are given, respectively, the annual costs of operation, and the cost of the water in cents per 1,000 gallons delivered to the consumers.

14. The water in each of the supplies mentioned would be subjected to such treatment as would bring all to

conform to the same standards, as to purity and softness, and the costs of such treatment and treatment-works are included in the estimates. The estimates of cost of construction include land, water sources and supply-works, new street mains in Plainfield, a new elevated reservoir, and all works necessary to put soft pure water into the houses of the consumers. The estimates of annual cost of operation include interest, amounts to put into a sinking fund that will provide revenues from which to renew each part as it is worn out or replaced, all labor, fuel, supplies, ordinary repairs, administration charges and maintenance charges on all parts of the works.

15. I find, on an analysis of the advantages and disadvantages of the different alternatives that either Plans E or F could advantageously be adopted by the city in case it be decided to construct a municipal supply.

16. I am of the opinion that, the rates now charged by the Water Company being assumed to be fair, and they have been so declared by more than one investigating committee, it would be impracticable for the Water Company to carry out the desirable improvements to increase the supply and soften the water unless the rates were increased by a considerable percentage.

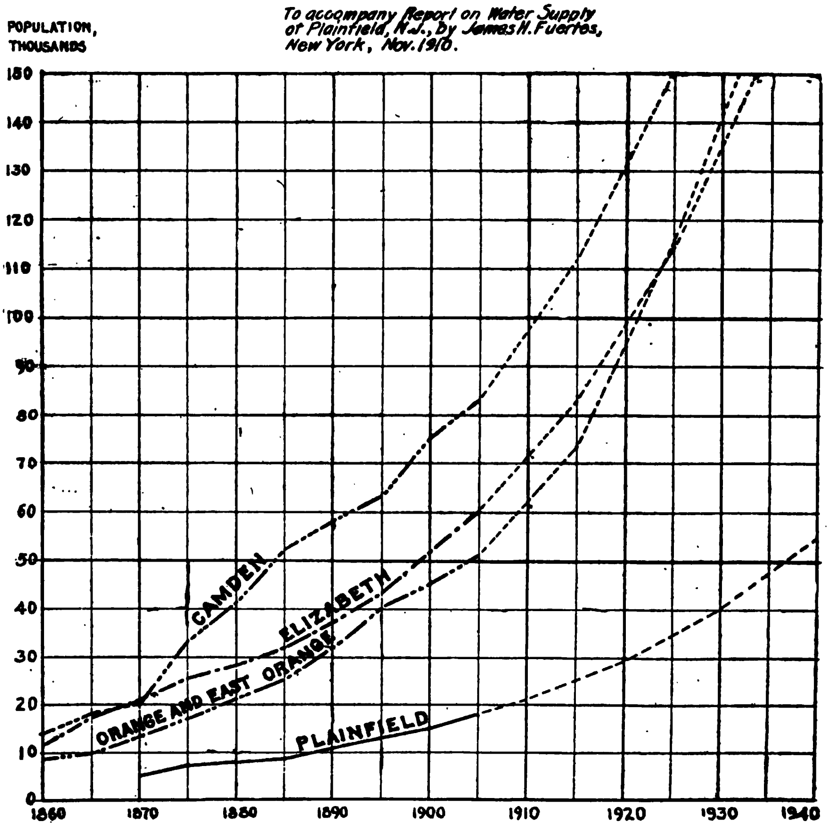
17. I believe that, as the city can secure a municipal supply at reasonable cost, and, therefore, is not compelled, to make another contract with the Water Company, the desirability or not of making such a contract depends largely upon whether or not the city has sufficient confidence in the Water Company to accept, irrespective of contractual obligations, its promises and concede its ability to look ahead and provide for future needs in advance of the requirements. It is, truly, a matter of confidence, for the reason that no contract that could be drawn up in advance would protect Plainfield's interests in case the Company was not physically able, or did not feel inclined, or could not afford, to live up to its terms. Engineering ability of a high order, executive ability and foresight on the part of the management, and ample financial resources are all necessary in order to make the interests of the Company and the consumer meet, and if Plainfield, through its past experience, or through its general view of the relations of Plainfield and all the other communities now supplied with water by the Plainfield-Union Water Company, is not satisfied that the present company can and will, for many years in the future, provide for Plainfield's needs as well, and for a total annual expense approximately as small as that for which the city could establish and operate a municipal supply, then Plainfield can and should decline to enter into another contract with the Company and proceed at once to establish a municipal supply.

18. I find that should Plainfield decide to establish a municipal supply the works can be built and put in operation before May 2d, 1912, the date when the present contract with the Plainfield-Union Water Company expires, providing authorization is granted in time to get the work ready for contract next spring.

The data upon which the foregoing statements are based will be found in the following pages.

FIGURE NO. 1
DIAGRAM
SHOWING POPULATION OF SEVERAL CITIES OF NEW JERSEY SIMILAR IN CHARACTER TO PLAINFIELD TAKEN FROM UNITED STATES AND NEW JERSEY STATE CENSUS REPORTS.

To accompany Report on Water Supply of Plainfield, N.J., by James H. Fuertes, New York, Nov. 1910.



PART II.

Growth of Plainfield and Water Supply Requirements.

Population—In the following report the city of Plainfield has been considered separately from the borough of North Plainfield, each having its own municipal administration. At present they are supplied by the same water company, the water distributed to North Plainfield passing through the mains in the streets of Plainfield. The population of Plainfield, which was incorporated as a city in 1867, is reported in the United States and New Jersey State Census since 1870 as follows:

	Plainfield.	Borough of N. Plainfield.
1870	5,095	.....
1875	7,216	.....
1880	8,125	.....
1885	8,913	.....
1890	11,267	.....
1895	13,629	4,245
1900	15,369	5,009
1905	18,468	5,016
1910	22,000*	6,000*

*Estimated.

On Figures 1 and 2 are plotted the populations of Plainfield (exclusive of North Plainfield), Camden, Elizabeth, Orange, and East Orange. On Figure 1 the different curves showing the growth and population are plotted to correspond to the years indicated at the bottom of the sheet. The populations determined from the censuses are shown in full lines. On Figure 2 these curves of population are re-drawn so that they cross when their populations are 24,000, and the Plainfield curve is extended in a dotted line at the rate of 3.7% per year which appears to be a fair rate to assume for the growth of this locality, starting from a population of 24,000, judged by the rates of growth of Elizabeth, Camden, Orange and East Orange.

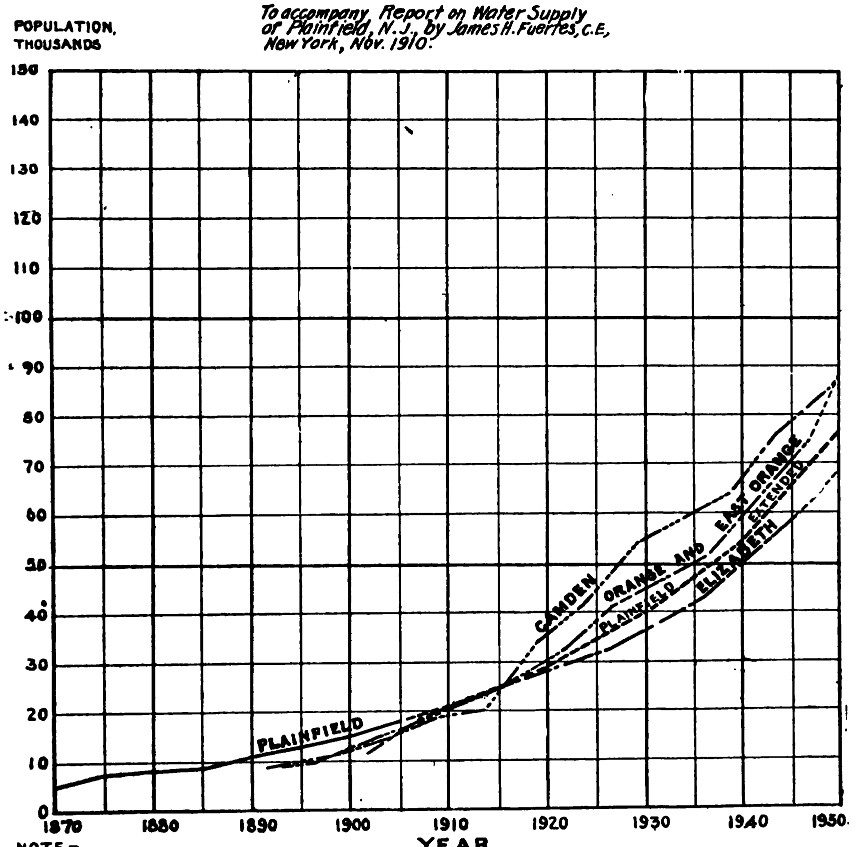
The population of Plainfield is essentially residential although there are several manufactories of considerable size located within the city limits. In my judgment the character of growth in the future will probably be similar to that in the past, except that the relative percentage of manufacturing population may increase. Plainfield, however, is likely to remain essentially a high class residential district and its rate of growth should be not far from that of Orange and East Orange from the time their populations were 24,000. The curve for the future growth of Plainfield, as shown upon this diagram, has been used as the basis for the estimates of water supply requirements. The years at the bottom of Figure 2 refer to Plainfield only. From this diagram it will be seen that the estimated population of Plainfield in 1910 is 22,000 increasing to 55,000 by 1940. On the same basis the estimate of the combined populations of Plainfield

FIGURE NO. 2

DIAGRAM

SHOWING ESTIMATED FUTURE RATE OF GROWTH OF PLAINFIELD
BASED ON PAST GROWTH OF SEVERAL CITIES OF NEW JERSEY
SIMILAR IN CHARACTER TO PLAINFIELD
POPULATIONS TAKEN FROM UNITED STATES AND
NEW JERSEY STATE CENSUS REPORTS

*To accompany Report on Water Supply
of Plainfield, N.J., by James H. Fuertes, C.E.,
New York, Nov. 1910.*



NOTE –
YEARS REFER TO PLAINFIELD ONLY. POPULATIONS OF OTHER CITIES LOCATED SO AS TO CROSS AT 24,000.

and North Plainfield would be 28,000 in 1910, increasing by 1940 to 70,000.

Estimates of future population are always necessarily dependent upon the judgment of individual estimators, and therefore, likely to be in error; nevertheless it is necessary to have a basis for properly proportioning the sizes and capacity of water works intended to serve for the next ten or twelve years, and permit of extensions to serve the future populations some thirty years hence.

The Quantity of Water Required—Plainfield and North Plainfield have been supplied with water since 1891 by the Plainfield-Union Water Company, or its predecessors, the total quantities pumped monthly during the years 1891 to 1910, as furnished by the Plainfield-Union Water Company, are given in Table I, Appendix B.

It will be observed on a study of these records that the monthly rate of consumption varies greatly, showing a general tendency to increase from year to year. This monthly variation in consumption is due to the greater use of water in the summer time for sprinkling of lawns, etc., and to the wastage of water in the winter time to prevent freezing, in addition to other special causes common in all cities. A careful study of these data indicates that the maximum monthly consumption is about 125% of the average monthly consumption. From general experience it would be safe to assume that the maximum daily consumption would be about 125% of the maximum daily consumption per month, or about 156% of the average daily consumption for the year.

In estimating the amount of water which should be provided for the water supply of Plainfield in the future, it is necessary to take into account the population of the city and its growth, the per capita consumption of water, the allowances to be made for fire service and the rate at which the water may be drawn from the mains for maximum service.

Based upon the pumping records given in Table I, Appendix B, and apportioning the total pumpage to Plainfield and North Plainfield in proportion to their populations, Table I, Appendix A, has been prepared; this shows that the water consumption at Plainfield averaged 42 gallons per capita in 1895, 52 gallons in 1900, 68 gallons in 1905 and 94 gallons in 1909. This gradual increase in per capita consumption is normal, and is to be expected in growing cities. It would be unwise to assume that the rate of growth of per capita consumption has ceased. The water consumption of cities is made up of four principal elements, the domestic consumption, the water used for public purposes, the

water used for manufacturing purposes and the unaccounted-for water which would include wastage, errors in estimating the quantity of water used, leakage from street mains, slip of pumps and other losses which can not well be prevented or detected.

In communities using water solely for domestic purposes, with no fire protection and no public or manufacturing uses, under American conditions the per capita consumption of water will normally be about 30 gallons per day, and this is the minimum figure which could be expected in any community of reasonable size. When water is used for street sprinkling, fountains and other uses of a public nature, the quantity so used will ordinarily range about 5 gallons per capita per day. If there are no manufacturing interests in the town 35 gallons would represent approximately the quantity of water used per capita and an allowance of 25% of this for slip of pumps, leakage of mains, under-estimating of quantities, etc. would bring the total consumption up to about 42 gallons per capita. When manufacturing industries are established in the town the per capita consumption will, of course, increase in accordance with the amount of water used for these purposes. In some cities the quantity used for manufacturing greatly exceeds that for all other purposes. Plainfield already has a number of manufacturing establishments using water and the total average consumption per capita has increased from 42 to about 90 gallons per day. I believe that this latter figure is somewhat in excess of the true amount, owing to errors in estimating the pumpage. In my judgment it would not be wise to neglect to take into account the probable increase in rate of consumption as well as in population, as the city grows in size, and I have assumed as fair that by the time new works can be established, bringing the water into the city at higher pressure, and consequently making almost certain a somewhat greater loss of water through leakage and wastage than under the lower pressure now supplied, that the per capita consumption will be about 85 gallons per day, and that this figure will gradually increase until by 1950 it will have reached 100 gallons per capita per day. These figures correspond closely with actual experience in cities of about the size and character of Plainfield, and while it would be desirable if possible to reduce the leakage and wastage to as small figures as practicable it would not be safe in providing for works for the future to assume that such great care will be taken to husband the supply as would warrant using smaller figures and providing for plants of smaller capacity. Based upon the estimated future populations shown in Figures 1 and 2 and upon the per capita water consumptions as described, Table II, Appendix A, has been prepared to show the

future water supply requirements for Plainfield from 1910 to 1940. In providing works for a municipal supply it is necessary to take account not only of the average daily consumption, but also of the variation in rate of consumption from day to day and from hour to hour, and additional allowances must be made for water for fire protection, assuming that fires demanding large quantities of water may occur at times when the ordinary consumption is at or near its maximum. The distribution pipes in the city and the main supply pipes bringing water to the city, in case compensating reservoirs are not provided, must have sufficient capacity to deliver the water at the maximum rate required. This would also be the case with pumping machinery designed to deliver the water directly into the distribution mains, on the assumption that there was no balancing or compensating reservoir. Compensating reservoirs should have sufficient capacity to balance the fluctuation in draft, while purification works should have a capacity equal to the maximum daily consumption.

To facilitate making proper comparisons between the different feasible plans by which Plainfield can secure a new and adequate supply of water I have assumed that all the supplies must conform to certain desirable standard requirements as to pressure, quality and the capacity.

Pressure—The pressure of the water in the street mains in Plainfield, near Fire Headquarters, if no water were being drawn from the mains by consumers, and if the stand pipe were full, would be about 69 pounds per square inch. The pressure at this point rarely or never reaches this figure, owing to the continuous taking of water out of the mains by the consumers.

It has been assumed in all the new projects investigated that the water should be delivered to a distributing reservoir on the mountains, to the northwest of Plainfield, located so that the water level therein, when full, would be at an elevation of 300 feet above sea level. This would give a total head on the mains in the streets near the Fire Headquarters of about 200 feet, or 86 pounds per square inch, no water being drawn from the mains. By properly proportioning the sizes of the pipes between this reservoir and the connection with the street mains it should be possible to maintain pressures, during all times, or about 70 pounds per square inch in the heart of the city, and this has been established as the desirable condition not inconsistent with economical operation.

Quality of the Water.—The water, from whatever source, should be clear, low in color, free from disagreeable tastes and odors, free from corrosive ingredients, free from excessive amounts of scale forming constituents, and safe and wholesome from a sanitary point of view. Those waters which do not nat-

urally conform to these requirements must be so treated as to render the water acceptable when judged by these general standards.

Capacities of the Different Parts of the Works.

In all the estimates of cost of construction and operation for new supplies the assumption has been made, based upon data given elsewhere, that the first installation should be for a capacity of not less than 4,000,000 gallons daily, and that the sources and works should be capable of further development to yield an average supply of at least 8,000,000 gallons daily.

As has already been pointed out, the rate of draft of the water will vary from day to day and will increase from year to year. The maximum daily rate of consumption for a few hours at a time may be at least twice the average daily rate for the year and if large conflagrations should be in progress at the time of the maximum daily consumption the rate of draft might be at least three times the average daily rate for the year. Experience in the management of water works plants, shows, however, that it is not necessary to provide the different parts of the works with sufficient capacities to accommodate the maximum rates of consumption. This is due to the fact that an extensive conflagration rarely occurs at the time of maximum daily consumption, and provisions for a considerably smaller quantity of water than such a combination would require affords practical protection. In Table II, Appendix A, Column 11 are given figures which in my judgment will afford ample protection for all contingencies so far as general supply works are concerned.

Capacities of Pumping Machinery.—Where no storage reservoir is provided for a city, (and a small stand pipe can not be considered as the equivalent of a storage reservoir) pumping machinery must, of course, be provided of sufficient capacity to meet the greatest rate of consumption likely to occur, as otherwise pressures would fall throughout the city if the pumps could not keep up the supply as fast as the water was taken away during fires. Where storage reservoirs are provided with a capacity equal to about a day's supply the quantity of water stored therein will balance the irregularities of draft sufficiently so that pumping machinery with a capacity equal to the maximum daily supply will be sufficient.

As a basis for determining upon the proper sizes of pumps to be used in connection with the various supplies investigated the capacities given in Table I have been assumed as necessary. In addition to supplying pumping capacity of the amount stated reserve units have been provided in each case, so that in case of accident to some of the machinery there will be a sufficient amount in service to keep up the supply.

TABLE I.

Average daily consumption.	Capacity of low and high lift pumps if compensating reservoir is provided.	Capacities of high lift pumps for direct service.
2,000,000	3,000,000	7,000,000
3,000,000	4,500,000	9,000,000
4,000,000	6,000,000	12,000,000
5,000,000	8,000,000	15,000,000

Capacities of Conduits.—In case direct pumping were resorted to without storage in or near Plainfield, the force mains from the pumping station connecting directly to the distribution mains in the city would have to be proportioned for the maximum rate of consumption, including fire service and would, therefore, have to have the capacities shown in Table II.

TABLE II

Average daily rate of consumption.	Conduit capacity required for direct service without storage.
2,000,000	7,000,000
3,000,000	9,000,000
4,000,000	12,000,000
5,000,000	15,000,000

For all supplies where the water would be delivered to a reservoir in or near Plainfield large enough to balance the daily fluctuation in the rate of consumption, the capacities of the pipe lines and conduits could be made sufficient to supply water at the maximum daily rate, as given in Table III.

TABLE III.

Average daily rate of consumption.	Capacity of conduits and supply pipes when compensating reservoirs are provided.
2,000,000	3,000,000
3,000,000	4,500,000
4,000,000	6,000,000
5,000,000	8,000,000

It has been found that a storage of from one-half a day to a day's supply is sufficient to balance ordinary fluctuations in draft and provide a sufficient fire reserve, with mains based on capacities sufficient to deliver the water at the maximum daily rates.

Compensating Reservoirs.—In all the plans discussed hereinafter provision is made for the construction of a compensating

or balancing reservoir at Washingtonville in the hills to the northwest of Plainfield. This reservoir, which is planned to have a capacity equal to one day's consumption of water, is to be placed so that the surface of the water in it, when full, will be at an elevation of 300 feet above sea level. With the reservoir so large as this the conduits bringing the water from the proposed gravity supplies and the force mains in pumped supplies would need to have a capacity only sufficient to deliver the water at the maximum daily rate of consumption.

The conduit lines from the impounding reservoirs, in connection with gravity supplies, and from pumping stations in connection with pumped supplies, are designed to be of cast iron, riveted steel or wood stave construction, according to the conditions of service and topography.

When properly built and protected from the corrosive action of the soil and of the water, all three classes of pipe are durable and suitable for conveying water for water supplies. No argument is needed to establish the suitability of cast iron pipe. Sufficient riveted steel pipe is also in use in this part of the United States by large corporations and municipalities to remove the suitability of this class of pipe from the field of discussion. The same may be said with regard to wood stave pipe, although less is known of this form of construction in the east than of the other two forms of pipe. Ten years ago there were practically no long lines of wood stave pipe east of the Mississippi River, although several hundred miles of such pipes have been built and laid in the western part of the United States. A large part of the information regarding the construction, serviceability and durability of wood stave pipe is to be derived from the experience of some of our western cities, irrigation companies and mining companies. Among the longest wood stave pipe lines in the east are the conduit supplying the city of Lynchburg, Va., which comprises over 20 miles of 30-inch wooden pipe, the conduit recently completed for Atlantic City, N. J., the pipe line constructed at Johnstown, Pa., by the Cambria Steel Works about five years ago, several large lines that have been constructed in Canada and several shorter lines in various states along the Atlantic seaboard. There is at the present time wood stave pipe in service which has been in continuous use for upwards of 60 years; and possibly over 100 miles of wood stave pipe now in service has been in use for upwards of 20 years.

In my judgment, when properly designed and constructed, wood stave pipe is sufficiently durable to warrant its construction in connection with long pipe lines for municipal supplies. Its low cost would permit of renewing the pipe about three times at a total cost for the three pipe lines no greater than for one

cast iron pipe line of the same capacity, considering pipes of the size contemplated in connection with Plainfield's new water supply. From my knowledge of the life of such pipe lines, when properly constructed, therefore, there is no question but that the investment would be a safe one; and their much smaller cost sometimes permits of the construction of long pipe lines, which could not be contemplated if cast iron or steel were the only materials available.

Purification Plants.—In connection with the water supplies from the Passaic River, the North Branch of the Raritan and the Lamington River purification plants of special types will be required. The Lamington River water will be the easiest and simplest to treat, and the water from the Passaic the most expensive of the river water supplies to purify. For the Lamington River water I have provided in the estimates for simple filters of the mechanical type, of special construction, designed to clarify the water in times of flood. In connection with these filters it is proposed to provide for the use of a coagulant at rare intervals, when the waters may be very turbid for a few days at a time. I have also planned to make possible the use of bleaching powder to complete the process of purification, the purification works to be located at the Washingtonville reservoir. In connection with the supply from the North Branch of the Raritan River at Ralston, which would be a gravity supply, and with the supply from the North Branch of the Raritan River at North Branch, which would be a pumped supply, and with the supply from the Passaic River at Berkeley Heights, which would also be a pumped supply, I have included in the estimates the cost of installing mechanical filter plants, and also provisions for using bleach as a finishing process.

In connection with the filter plant for the Lamington River supply no subsiding reservoirs would be required, and the filter plant would be given a capacity equal to the maximum daily rate of consumption. For the filter plants for the Raritan River supply from North Branch Station and for the Passaic supply from Berkeley Heights, coagulating basins would be required of the capacities given in Table IV.

TABLE IV.

Average daily supply.	Capacities of subsiding or coagulating basins.
2,000,000	1,000,000
3,000,000	1,500,000
4,000,000	2,000,000
5,000,000	2,500,000

For the filter plant for the Raritan supply at Ralston coagulating basins will be required of the capacities given in Table V.

TABLE V.

Average daily supply.	Capacities of subsiding or coagulating basins.
2,000,000	500,000
3,000,000	750,000
4,000,000	1,000,000
5,000,000	1,250,000

The filters best suited for the purification of the Lamington River supply would be mechanical filters constructed on the lines of the preliminary filters at Steelton, Pa., which can be constructed very simply and cheaply and are not at all difficult to manage. With these filters it would be unnecessary, in filtering water like that which would be supplied from the Lamington River reservoir, to provide for any subsiding basins as the filters will remove such turbidity, without difficulty, as may occur in this water.

The filters for the other supplies must be provided with subsiding and coagulating basins and must be constructed on a more elaborate and more expensive plan. In order to secure satisfactory purification from rapid filters, where the filters are depended upon to produce water both clear and free from bacteria, it is necessary with most waters to introduce into the water before filtration an artificial coagulating material, which will, by virtue of its stickiness, gather together in rather large masses the suspended impurities of the water until they form flocs too large to pass through the sand bed of the filters. The coagulant most commonly employed for this purpose, is a cheap variety of alum commercially designated aluminum sulphate. When aluminum sulphate is placed in water containing in solution the carbonates of lime and magnesia it immediately decomposes and changes to an inert harmless insoluble material having no longer characteristics of the original alum. The aluminum hydrate, which is the result of the reaction between the lime in the water and the aluminum sulphate, forms in the water quickly and appears throughout its volume in small white flakes of a gelatinous or sticky nature. These entangle and cement together the suspended matter in the water, including fine particles of clay, silt, organic matter and bacteria and when the water is then passed through a filter this coagulum and all the suspended impurities in the water are caught upon the surface of the sand where they gradually accumulate until the filter becomes clogged to such an extent as to require washing.

In connection with the Lamington River water a coagulant

will be required only for very short periods and on rare occasions; ordinarily the deep filters will themselves without the aid of a coagulant remove the suspended matter and bacteria sufficiently to make the water perfectly safe and satisfactory in appearance. These filters will, during the summer time when the water is clear, run for several months before cleaning becomes necessary, but during periods of muddy water, when a coagulant is being used they may require washing as frequently as every four or six hours until the muddy water period has passed.

The filters for the other supplies would have to use a coagulant practically all the time, and ordinarily would run from 10 to 16 hours between cleanings. The water of the Passaic River from Berkeley Heights would be the most expensive of the river waters to purify for reasons which will be described in connection with that particular supply.

For all the filtered supplies the filters would have a capacity equal to the maximum daily consumption as given in Table VI.

TABLE VI.

Average daily consumption.	Capacities of filter plants in million gallons daily.
2,000,000	3,000,000
3,000,000	4,500,000
4,000,000	6,000,000
5,000,000	7,500,000

Filters of the mechanical type using a coagulant are suggested as the most satisfactory for the purification of the waters under consideration in connection with Plainfield's proposed new supply. Slow sand filters, the other well known type, operate at such moderate rates that artificial coagulation is not necessary, the suspended matters iucluding the bacteria being arrested in the top layers of the sand by their interception and adherence to the sand grains. Biological actions which it is unnecessary to describe at length at this point materially assist in the purification of the water by slow sand filters. Filters of this type moreover can not successfully remove fine particles of clay from the water, when present in large amounts; neither can they remove a significant part of the stain or color acquired by waters from swampy districts unless a coagulant is used to aid the process. One of the advantages of using alum to assist in the process of purification is its power to decolorize peaty waters, the alum in some way rendering the coloring matters insoluble so that when coagulated into large enough masses they will be removed by the filters.

None of the waters under consideration in this report would

be likely to need decolorization to render them acceptable excepting perhaps the water of the Passaic at Berkeley Heights. This water, however, can be rendered bright, clear and colorless by the use of alum in connection with mechanical filters. There is no longer any uncertainty regarding the efficiency of properly designed and operated filters of this type. With respect to the removal of bacteria, their efficiency is as high as that of the slow sand filters, and with respect to the removal of color and turbidity their efficiency is much higher, assuming that both types of filters are properly and intelligently managed.

Softening Plants.—For all supplies which require softening the plants should have the capacities specified for filtration plants.

Treatment with Hypochlorite of Lime or Soda.—This process has passed the experimental stage, and is now used in from 75 to 100 American cities in connection not only with gravity supplies, but in cities supplied with filtered water, the hypochlorite treatment being given as a finishing process to guard against accidental disarrangement of the purification process. Among the cities using it are Cincinnati, O.; Columbus, O.; Council Bluffs, Iowa; Harrisburg, Pa.; Pittsburg, Pa.; Milwaukee, Wis.; Minneapolis, Minn.; Montreal, Canada, and many others.

Yields of Watersheds With Storage Reservoirs.

The records of flow of the Croton and Sudbury Rivers, extending over a long series of years, have been found to furnish reliable data for the estimating of stream flows and depletion of storage in their own as well as in other territories in the same general locality; and these data have been much used by engineers in designing storage reservoirs.

The rate at which water can be drawn continuously from a given watershed where favorable storage sites are available, is decidedly greater than the minimum or dry weather flow of the stream. During the winter and spring months when the stream flow is large, due to rain and melting snows and to the saturated condition of the ground, stream flows are relatively large; and by constructing storage reservoirs along the valley, a large portion of these excess flood waters, which normally would pass down the stream, can be held in storage to be drawn from during dry weather. From the records of several streams in this general locality it has been found that from 45% to 50% of the total annual rainfall runs off in the streams, the balance being absorbed by vegetation and lost by seepage and evaporation. If reservoir sites could be found in which all the stream flow could be stored and made available for use, it would be possible, therefore, in this general locality, to collect from 22 to 23 inches in depth of the total annual rainfall which would produce a yield

of a little over a million gallons of water from each square mile of watershed per day. If none of the stream flow could be stored along the valley, the yield of the stream might fall as low as about 90,000 gallons per square mile per day during very dry weather. The amount of storage that can be economically provided along the valley of a stream, therefore, determines how much water can be drawn from that stream daily between limits varying from a minimum of 90,000 gallons per square mile per day to a maximum of a million gallons per square mile per day.

Figure No. 3 shows the quantities of water that can be drawn daily from one square mile of watershed of the Sudbury and Croton Rivers with different amounts of storage and different percentages of water surface as determined from gaugings of these streams, extending over many years. On this diagram I have placed lines modified somewhat from both the Croton and Sudbury curves to indicate what, in my judgment, would be safe quantities to assume as available with different amounts of storage on the watersheds we here have under consideration.

When the continuous daily draft from a watershed is so great as to hold the water down below the crest of the dam continuously for more than two years the water is likely to become discolored, to emit disagreeable odors and to taste unpleasant. This limit is reached ordinarily when an attempt is made, by providing large storage, to continuously draw more than about 750,000 gallons of water daily from each square mile of watershed. Storage facilities sufficient to yield 300,000 to 500,000 gallons of water per square mile per day are very common, and ordinarily yield water of satisfactory quality, other things being equal. In order to yield the quantities of water required for Plainfield for many years to come the storage in the valley of the Black River above the proposed dam site need not be greater than will permit of a daily draft of about 300,000 gallons of water per square mile per day, which is a very moderate development. Other sites exist on the river and its branches which will permit storing sufficient water to increase the yield of the river, if necessary, to at least 12,000,000 gallons per day.

Effect on Water Powers of the Diversion of Water From Various Streams.

The streams in the vicinity from which supplies can be drawn for Plainfield are utilized for water power to greater or lesser extents and the diversion of the water from the streams for the supply of Plainfield would injure these water powers more or less, and compensation for this injury would necessarily have to be paid to the owners of the powers. The amount

FIGURE NO. 3

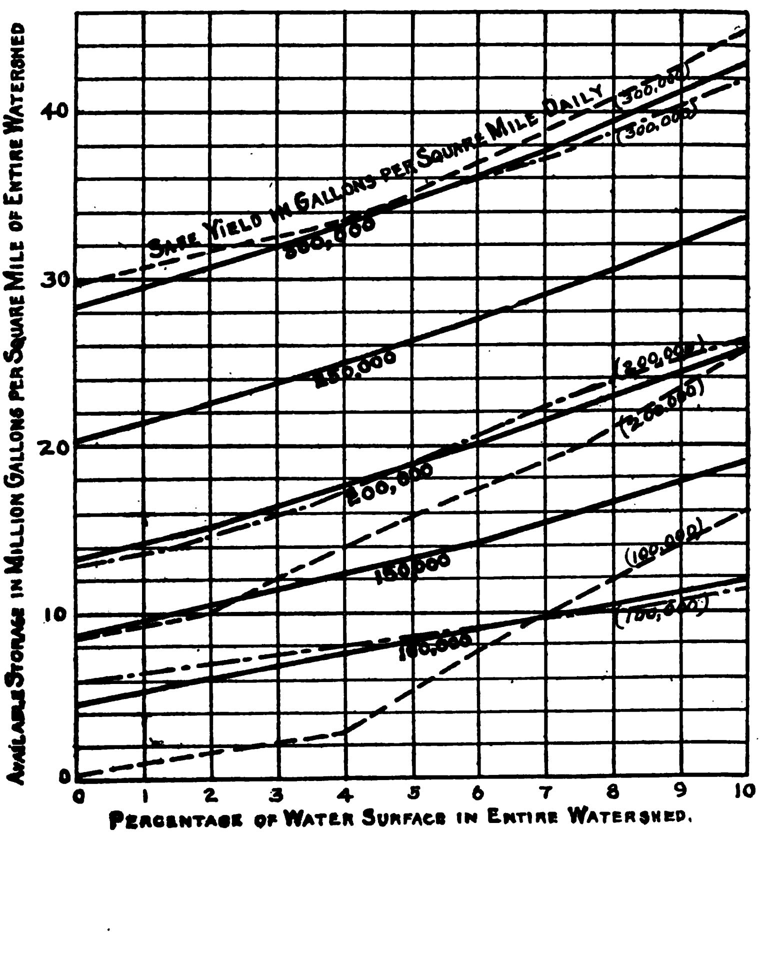
DIAGRAM SHOWING ESTIMATED DAILY QUANTITY OF WATER THAT CAN BE CONTINOOUSLY DRAWN FROM ONE SQUARE MILE OF TOTAL WATERSHED WITH DIFFERENT QUANTITIES OF AVAILABLE STORAGE AND DIFFERENT PERCENTAGES OF WATER SURFACE

ACTUAL SAFE YIELD OF CROTON WATER SHED SHOWN THUS —·—·

ACTUAL SAFE YIELD OF SUDBURY WATER SHED SHOWN THUS – – – –

ESTIMATED SAFE YIELD OF WATER SHEDS CONSIDERED IN THIS REPORT SHOWN THUS ————

To accompany Report on Water Supply of Plainfield, N.J, by James H. Fuertes, C.E. New York, Nov. 1910.



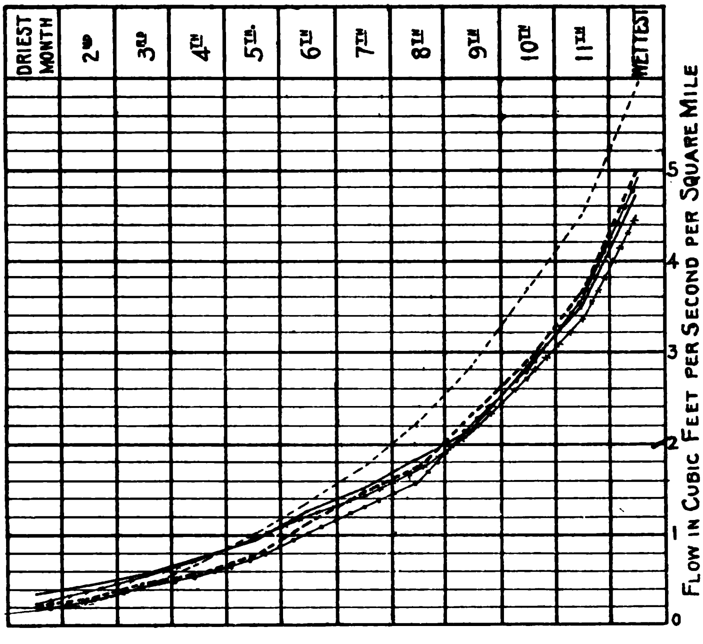
of power that can be derived from a given stream depends upon the quantity of water flowing in the stream and upon the head available due to the fall or slope of the bed of the stream through the property on which the water power exists. The available head is established in each case by the amount of fall than can be profitably converted into power, and the right to use the power developable from such head belongs to the land. Under the law parties having riparian rights in streams are entitled to the enjoyment of the use of the waters of the stream in its natural condition, and any diversion of these waters which affects the parties owning powers down stream must be compensated for in money. It is not, under the ruling and accepted decisions of the courts possible to compensate "in kind," that is even though, by the construction of dams and impounding reservoirs whereby during dry weather larger quantities of water could be let down into the stream bed than would naturally flow therein in dry weather, the provision of this relief would not be considered as compensation under the law. Under these circumstances it is necessary to ascertain what damage would be done to each of the water powers on the various streams from which it is possible for Plainfield to secure an additional supply.

The flows of streams vary from day to day in amount. No rule exists or laws are known by which the actual stream flow can be predicted or calculated either in the future or in the past at any given moment. Rain and snow are the sources from which all stream flow arises, and though the amounts of these may be known the rates at which the water will reach and run off in the stream can only be determined approximately from these data. Rains falling on the surface of frozen grounds, or on ground saturated with water, swell the stream flows enormously in proportion to rains of equal intensity and volume falling in mid-summer when the ground is dry. Frequently very heavy rains in the summer time will be completely absorbed by the ground and held back by vegetation and by capillary attraction in the soil, so that practically none reaches the rivers and streams. Frequently the water which is seen running in streams in August, September and October is rain which has fallen in the preceding winter or spring, and, percolating deeply into the soil and crevices of the rock has gradually worked its way out in the form of springs several months later. These conditions are what cause stream flow to vary so greatly from season to season and from day to day.

In developing a water power on an ordinary stream it would manifestly be unwise to attempt to provide as much power as the flood flow of the stream would furnish, because, although

FIGURE NO 7

DIAGRAM SHOWING FLOWS, BY MONTHS ARRANGED IN THE ORDER OF DRYNESS OF CROTON AND SUDBURY RIVERS AND PERKIOMEN, NESHAMINY AND TOHICKON CREEKS



PERKIOMEN ————
NESHAMINY - - - - - -
TOHICKON ....
CROTON -x-x-x-x-
SUDBURY -•-•-•-•-

NOTE - For the streams under consideration as possible supplies for Plainfield, it is assumed that the flows for the first 8 months in the order of dryness will be equal to those of the Perkiomen and for the last 4 months to those of the Croton River.

enormous in volume, the duration of the time when such large flows would prevail would be so short that possibly only for a few days in the year could the entire power be relied upon. On the other hand, it would be unnecessarily conservative to provide only as much power as the minimum of flow of the stream would take care of, as this minimum flow might prevail only for a few days in the year whereas for several months many times this amount of power could be utilized. The ordinary custom in designing powers is to develop them to the point which would correspond with the flow of the stream in about the fourth or fifth month in the order of dryness; not in the calendar order of the months. The driest month of the year may be almost any of the calendar months, by dryness designating, of course, the month of least stream flow. In order to have a rational basis on which to examine into the effect of the diversion of the water of the various streams on the water powers thereon, I have prepared a diagram, Figure 7, on which I have placed curves showing the average flows, in cubic feet per second per square mile of watershed, of the Perkiomen, Neshaminy, Tohickon, Croton and Sudbury Rivers for the different months arranged in the order of dryness or least stream flow. The records of the Perkiomen, Neshaminy and Tohickon streams date from 1884; the Croton records from 1868, and the Sudbury records from 1875. These records are of continuous gaugings of these streams since the dates mentioned, and the curves have been prepared by selecting the months in each year, in their order of dryness, for the entire period covered by the records, and plotting upon the diagram for each month these averages. The data from which this diagram has been prepared are contained in Table VII.

TABLE VII.

Months.	Perkiomen 152 Sq. Miles 1884 to 1903 inclusive	Neshaminy 139.3 Sq. Miles 1884 to 1903 inclusive	Tohickon 102.2 Sq. Miles 1884 to 1903 inclusive	Croton 338 Sq. Miles 1868 to 1899 inclusive	Sudbury 75.2 Sq. Miles 1875-1897 inclusive
Driest	0.36	0.21	0.19	0.26	0.19
2nd	0.43	0.30	0.25	0.40	0.27
3rd	0.58	0.44	0.42	0.55	0.44
4th	0.75	0.59	0.67	0.75	0.58
5th	0.94	0.79	1.01	0.93	0.77
6th	1.23	1.15	1.39	1.21	1.05
7th	1.50	1.49	1.74	1.42	1.30
8th	1.82	1.79	2.23	1.76	1.60
9th	2.17	2.34	2.82	2.17	2.20
10th	2.84	2.90	3.68	2.72	2.81
11th	3.49	3.68	4.48	3.40	3.57
Wettest	4.69	5.00	5.96	4.49	4.93
Average	1.73	1.72	2.07	1.67	1.64

The watersheds under consideration are all somewhat

smaller than those from which these data have been compiled, and are somewhat different in topographical features, the main difference being that on practically all the streams under consideration there exist extensive areas of flat country thickly grown up with brush and trees which will contribute to equalizing the stream flow. This would result in less extreme floods. Whether or not the effect of the larger water areas would be to decrease the stream flow in dry weather by evaporation and absorption by plant life than to increase it by virtue of the greater storage is questionable. I am inclined to believe that the effect would be more toward the latter condition than toward the former. The lowest recorded gauging of the Raritan, for instance, places its flow at 0.14 per cubic foot per second per square mile of watershed, which is considerably higher than the lowest recorded flows of any of the streams given in the tabulation, excepting the Perkiomen. In my judgment, fair figures to assume for the streams under consideration would be those for the Perkiomen for the eight driest months and for the Croton for the remaining four months. Putting these in tabular form, the average monthly flows in feet per square mile of drainage area, arranged in the order of dryness, would be, for the streams under consideration, as given in Table VIII.

TABLE VIII.

Months. Arranged in the order of dryness.	Stream flow in cubic feet per second per square mile of drainage area.
Driest	0.36
2nd	0.43
3rd	0.58
4th	0.75
5th	0.94
6th	1.23
7th	1.50
8th	1.82
9th	2.17
10th	2.72
11th	3.40
Wettest	4.49
Average	1.69

A supply of water for Plainfield taken from the Lamington River below Hacklebarney would interfere with developed water powers at Pottersville, Vleittown, Burnt Mills, Raritan and New Brunswick, and with many undeveloped powers along the river.

A supply taken from the North Branch of the Raritan at Ralston would interfere with developed powers at Ralston, Raritan and New Brunswick and with a small amount of undeveloped and abandoned powers at several places.

A supply taken from the North Branch at North Branch

Station would interfere with developed powers at Raritan and New Brunswick.

A supply from the Passaic River at Berkeley Heights would interfere with developed powers at Chatham, Stanley, Little Falls, Paterson and Passaic.

It is unnecessary to consider each individual power at this time. Frequently two or more powers may be supplied from the same dam and utilize the same head, but have different wheel or turbine capacities; and few of the powers are developed or used to their economical limits. The error, if any, will be on the side of safety if the powers be considered in groups assuming each to be capable of producing all the power that can be economically developed at that site with the available stream flow and head.

If a dam be built at the site mentioned, for the purpose of supplying Plainfield with 8,000,000 gallons of water daily some years hence, there will be some months each year when, the natural stream flow at the site being less than 8,000,000 gallons daily, water would be drawn from the reservoir and none would flow down stream from the 26.85 square miles of watershed above the dam. At such times the only water for the supply of the mills at Pottersville would be what would be yielded by the 6.15 square miles of watershed between Pottersville and the dam below Hacklebarney, the total flow from the watershed above this dam having been diverted to Plainfield. Whenever the flow at the dam below Hacklebarney would exceed 8,000,000 gallons daily, then the effect on the Pottersville mills would be to deduct 8,000,000 gallons daily from the available natural stream flow at the Pottersville mills, and the reduction in power would be measured by this reduction in stream flow.

In Appendix D calculations are given showing the effect, on all the powers mentioned, of taking 8,000,000 gallons daily from the different streams; and these calculations are summarized in the tabulations given hereafter. The calculations have been made for the economical limit of development, and for 24-hour powers.

A 24-hour power is one in which the natural stream flow only is utilized, and would, therefore, be available 24 hours of each day continuously. A 10-hour power is one in which, by means of storage in the pond behind the dam the stream flow on nights and Sundays can be stored up to be let out together with the natural flow of the stream during 10 hours of each of the 6 week days. Not many of the powers under consideration have sufficient storage to derive much benefit therefrom, though some of them use flash boards on the dams.

While the true value of the damages to a water power by

the diversion of a portion of the stream flow is the difference in value of the property before and after the taking, the depreciation must be determined by taking into account all the circumstances, among which is the extent to which the power is reduced. Frequently, where the interference is serious, it is more satisfactory to purchase the works outright than to try to reach a fair compensation for the damages done by diversion. This is usually the case with smaller and unimportant powers, or those which have fallen into disrepair.

One method which is sometimes used to approximate the damages done by diversion is to ascertain the amount that the power is reduced, calculate the annual value of that amount of power at prevailing or usual rates, and capitalize this annual sum at a fair rate of interest. This is the method that has been followed in this investigation, and although open to criticism in certain particulars it appears to be the most convenient for use in this preliminary investigation. It is believed that the amounts arrived at will prove ample, particularly in view of the fact that the damages are based on the economically developable power rather than on the powers actually in use.

Provisionally I have assumed that a 24-hour power is worth $50.00 per H. P. per year and a 10-hour power $30,00 per H. P. per year and that an undeveloped power has a potential value of $10.00 per year per horse power. The following summary, Table IX, which includes all the powers that would be affected by the construction of the reservoir on Lamington River below Hacklebarney, indicates that for this supply the diversion of 8,000,000 gallons of water daily from the river would require an outlay on the part of the city of $180,000.00 to compensate the various mill owners for the diversion of the water.

TABLE IX.

Summary of Developed Water Powers Affected by Taking 8,000,000 Gallons of Water Daily From the Lamington River at the Proposed Reservoir One Mile Below Hacklebarney.—Based on 24-Hour Powers.

Location of Powers.	Present net amount of power used.	Limit of economically developable power with natural stream flow.	Average reduction of developable power by diversion of 8,000,000 gallons daily.	Average reduction of powers already developed by diversion of 8,000,000 gallons daily.
	Horse Power	Horse Power	Horse Power	Horse Power
Powers between Pottersville and proposed new reservoir.	213	220	58	58
Powers at Vleittown	25	90	26	..
Power at Burnt Mills	25	37	5	..
Raritan	200	510	17	..
New Brunswick	150	750	14	..
Totals	613	1607	120	58

The measure of the damages by the diversion of the water power from the Lamington River, based upon the data contained in the above table would be derived as follows:

Total reduction of power	120 H. P.	
Assumed value of 1 H. P. per year	50.00	
Total annual value of reduction of power	$6,000.00	
Capital which at 5 per cent. interest would produce $6,000.00 per annum		$120,000.00
Reduction of power of undeveloped powers	300 H. P.	
Assumed value of 1 H. P. per year	$10.00	
Total annual value of reduction of power	$3,000.00	
Capital which, at 5 per cent. interest would produce $3,000.00 per annum		60,000.00
Measure of total damages to water powers		$180,000.00

The diversion of 8,000,000 gallons of water daily from the North Branch of the Raritan at Ralston will affect the powers at that point, the undeveloped power above Far Hills belonging

to the Somerset Club and the powers on the Raritan at Raritan and New Brunswick. The effect on these lower powers, however, will be so small as not to interfere at all with any powers now developed, the minimum flow of the stream providing more water than will be necessary to supply these powers even after the diversion of the water above.

The powers at Ralston, however, would have to be acquired, and a fair estimated value therefor, in addition to compensation for interference with the other developed and undeveloped powers below would, in my judgment, be covered by an allowance of $75,000.00.

The diversion of 8,000,000 gallons daily at North Branch would not affect any of the powers below, as at present developed, and would not reduce the available power at these sites more than about 15 H. P. if developed to three times the present limit. To provide for possible contingencies here the sum of $15,000 has been allowed in the estimates.

The diversion of 8,000,000 gallons daily from the Passaic River, at Berkeley Heights Station would leave the powers at Chatham and Stanley reduced by an average of about 38 H. P. for half the year and would reduce the powers at Little Falls, Paterson and Passaic by about 60 H. P. in the aggregate during a few months each year. For the diversion of this water, therefore, an allowance of $100,000 has been made in the estimate of cost of the supply from the Passaic from Berkeley Heights.

PART III.

The Water Supply of Plainfield.

GENERAL DESCRIPTION.

Historical—Until the fall of 1891 Plainfield had no public water supply, the citizens depending upon driven or dug wells, and the city, for fire protection, depending upon walled cisterns under the sidewalks at various places.

The first systematic attempt to secure a municipal water supply was recorded in a resolution of Common Council, passed November 1st, 1886, appointing Mr. C. P. Bassett, C. E., to make a survey and preliminary report on water and sewerage systems for Plainfield in accordance with the report of the Committee on Fire, Water and Lamps. Mr. Bassett's report, in the matter of water supply, reviewed the advantages and disadvantaves of yravity supplies from Green Brook and Stony Brook and of a pumped ground water supply from the territory where the present Netherwood pumping station is located, recommending the latter source on the ground of quality and cost. The recommendations were submitted to Mr. Rudolph Hering, C. E., for review, and received his approval April 27, 1887.

The construction of the present water supply works was undertaken by the Plainfield Water Works Company under a contract between that company and Plainfield entered into in December, 1890. Before much work had been done, however, the company failed and the Plainfield Water Supply Company, a corporation created by an act of legislature of New Jersey, approved April 2nd, 1869, extended by a supplement to the charter passed in 1874, purchased the property of the Water Works Company, completed the works in the summer of 1891, and secured a contract with the city, dated May 2nd, 1892, to supply it with water. For nearly 20 years after its creation, and 16 after the passing of the supplement to the Charter, this company did no work towards securing a source of supply or a system of pipes to distribute water, although the organization was kept alive by holding meetings, electing officers, etc.

At the time there existed another water company known as the Union Water Company which operated under a charter granted by the State of New Jersey, March 17, 1870, and which had the right to supply water throughout Union County. This company had no source of supply of its own, but in 1893 or 1894 laid a line of pipes, leading to the east from the Netherwood pumping station and stand-pipe, to supply water within its charter territory.

By an agreement of merger and consolidation dated September 21st, 1906, the Plainfield Water Supply Company and the

Union Water Company became the Plainfield-Union Water Company, the corporation now supplying Plainfield, North Plainfield and towns to the east as far at Elizabeth. Additional companies, linked in the same system, supply many other towns in a large territory extending south as far as the Raritan River and east to Staten Island Sound. The mains of these companies are now inter-connected at several points. As operated until April, 1894, all the water from the Netherwood plant was delivered into the street mains of Plainfield and North Plainfield.

From April, 1894, until early in 1910, part of the water from the Netherwood pumping station has been delivered to towns to the east through the mains of the old Union Water Company. In January, 1910, 51,737,500 gallons are reported as having been pumped to the east out of a total of 146,185,780 gallons taken from the ground at the Netherwood station. In February of this year the meter which had been used to measure the water pumped to the east was taken out and presumably moved to El Mora, and from that time on no record is available of the quantity of water delivered to the east from the Netherwood pumping station. During the early summer of 1910 a portion of the water supplied to the towns east of Plainfield was pumped into the Union Water Company's mains from the mains of the Middlesex Water Company by a booster pump located at El Mora, near Elizabeth.

The records of the pumpage of water from the wells at the Netherwood pumping station, as well as the fluctuation of the surface of the water in the wells, as determined from month to month, for the entire period since 1891, are given in Appendix B. These data were supplied through the courtesy of Mr. Frank Bergen, President of the Company.

Previous Investigations.

1894 Report.—From time to time since the construction of the works the uneasiness of the citizens of Plainfield, as to their water supply conditions, has manifested itself in the appointment of committees to examine into and report upon the matter. The first report was made by a committee consisting of Messrs. George H. Frost, E. N. Erickson and S. A. Ginna, appointed by Councils in 1894, a few months after the water supply company had begun to supply water to Fanwood, Westfield, Cranford, Roselle and Elizabeth with water drawn from the Netherwood wells.

This report set forth, in brief, that in the committee's opinion the sources from which the Netherwood wells were supplied were local; that the continued pumping of the Netherwood wells had lowered the water in neighboring wells, necessitating in some

cases the deepening of the wells to secure a supply; that there were indications of the general lowering of the entire water table in that vicinity and the consequent tendency towards partial exhaustion of the storage supply. The committee felt, however, that there was no immediate danger of an insufficient supply to meet the needs of the city, but that the probability of a much diminished supply in the near future was imminent.

The remedy suggested by the committee was that a sufficient watershed should be secured as free from contaminating influences as possible and that only such supply should be taken from it as would be needed by the citizens of Plainfield and such adjoining communities as could be safely supplied.

The report also set forth at length the replies to several questions submitted to Mr. Craig A. Marsh, Corporation Counsel, regarding, among other things, the right of the company to supply other cities with water taken from the Netherwood wells, the nature of the company's franchises, the relations of the city and company in the matter of rights in the sources of supply, their relations in case the city should establish a municipal supply, etc. This report contains much useful data regarding the practical and legal phases of the question.

1904 Report.—In 1904, ten years later, Messrs. Joseph O. Osgood, W. L. Saunders and B. S. Church, three engineers of prominence and large experience, residing in Plainfield, gave their services to the city in further investigation of this subject, at the request of the Street Committee of Common Council. This committee was requested to advise the Street Committee and the Common Council whether it would be to the benefit of the City of Plainfield to own its own water supply system.

The report is brief and in substance was to the effect that it would be to the benefit of the City of Plainfield, as a measure of economy as well as for other reasons, to own its water supply system, although no great reduction in the existing water rates would be looked for as a result of such ownership; that it would be advisable to acquire the plant of the Plainfield Water Supply Company if that could be done at a reasonable cost either by purchase or condemnation; that if it should prove impracticable to acquire the present plant of the Plainfield Water Supply Company, the city would be justified in constructing new works, if necessary, independently of the Water Company; that it would probably be best to buy the whole of the existing plant within the limits of the city and construct anew only in case the present plant could not be acquired on the proper basis; that in case Plainfield should purchase or acquire the works of the water company, North Plainfield might purchase so much of the plant as lay within its boundaries and take water from Plainfield on

some mutually agreeable basis. This report was not rendered until February 6th, 1905, and was referred by Common Council to the Committee on Public Affairs.

Adoption of Water Works Act—At a meeting of the Committee on Public Affairs held July 14th, 1905, it was decided to recommend to the Common Council that the statute under which Plainfield could acquire the power to take water, from such sources as may be practicable, into and through the city, or to purchase water works from any water company, or to condemn such water works, found in general statutes, page 646, et seq., be submitted to a special election; and on August 4th, 1905, reported back to Common Council with their recommendations the report of Messrs. Osgood, Saunders and Church. At a meeting held October 2nd, 1905, Common Council adopted a resolution providing for a submission to the voters of the city at the general November election of that year the question of the adoption for the city of the new water works act. The matter failed of passage that year and the recommendation was made during the succeeding year that no action be taken at that time for resubmission of the question to the voters at the general election in November.

1909 Report.—On January 1st, 1907, Common Council, by resolution, appointed a committee of 15 members, three from the Common Council, eight citizens of Plainfield selected by the Mayor, two citizens from North Plainfield, the Mayor of the Borough of North Plainfield and the Mayor of the City of Plainfield. This committee consisting of Charles J. Fisk, Mayor of Plainfield; Newton B. Smalley, Mayor of the Borough of North Plainfield; George P. Mellick, Ralph I. Tolles, W. S. Tyler, members of Plainfield Common Council; Wm. R. Craig, W. A. Coddington, John B. Dumont, George H. Frost, Henry L. Hall, W. Newcorn, Joseph O. Osgood and Harry G. Runkle, members appointed by the Mayor, and Justus H. Cooley and W. L. Saunders, members to represent the Borough of North Plainfield, organized on January 11th, 1907, and submitted its final report January 4th, 1909. The committee set out to investigate:

(a) "The question of providing the City of Plainfield independently of the Plainfield Water Supply Company, such quantity of pure and wholesome water as may be required for domestic or other purposes of the inhabitants. The supply of water to be obtained from such source or sources as may be possible, either within the said limits or outside, as may be determined upon by competent engineers."

(b) "In case the city shall decide to install its own water works, to consider the matter of the construction of its own distributing system, or of taking or of acquiring, either by purchase or condemnation the property of the Plainfield Water Supply Company, that is to say, the

water mains, pipes, hydrants and other connections, valves or gates or special castings of every description now owned by the Plainfield Water Supply Company and laid in the streets, alleys and other public places in the City of Plainfield, being the entire system in use by the Plainfield Water Supply Company, for conveying water to the City of Plainfield for the use of the inhabitants of said city, but not including the main line of pipes for conveying water through the City of Plainfield for other municipalities."

(c) "To consider the question of acquiring the wells, stand pipe, machinery, real estate, buildings, in fact the entire plant and all property, including all pipe lines, etc., now owned by the Plainfield Water Supply Company, also all rights and franchises now owned by the Plainfield Water Supply Company and within the limits of said City of Plainfield, either by purchase or condemnation."

(d) "Also to examine into the rights of the Plainfield Water Supply Company under its charter or other legislative acts, to take water from within the limits of the City of Plainfield and to sell the same to any party or parties, except to townships or municipalities immediately adjoinin the City of Plainfield, either directly or indirectly, to another company formed for that purpose."

(e) "To take up, with the authorities of North Plainfield the question of securing for the Borough of North Plainfield like advantages and acting jointly with them on this question."

The engineering committee of this water committee reported in brief that the present works in Plainfield and North Plainfield (1908) were worth approximately $420,397.72, as stated by Mr. Frank Bergen in a letter to Mr. Osgood, but that probably the cost of new works if constructed at the present time would exceed the original cost, depreciation not being taken into account.

The report calls attention to the lowering of the ground water as shown by the water company's records, and calls attention to the fact that the rapidly increasing draft on the ground water was reducing the level of the water in the wells before the dry weather in the summer and fall of 1907.

They stated that they were of the opinion, with the information at hand, that no other source of water supply for the city should be considered, so long as the underground source now tapped by the Plainfield-Union Water Company was sufficient for the needs of the community; that it was desirable to restrict the drafts on the present plant to the needs of the immediate community rather than construct an additional plant to still further deplete this supply; that it was desirable in case the city was to own its own water works that it acquire the plant of the water company; that any condemnation or purchase of the property which left the water company free to continue to draw on the underground waters of the basin from which

it now pumps, would be an unsatisfactory adjustment of the matter; that an arrangement under which the local governments interested would unite in acquiring the water works and pipes within the boundaries of Plainfield and the townships and boroughs of North Plainfield and Fanwood and in securing the control of the water supply for their joint benefit, would seem to offer the best results for the community as a whole. The question of entering into a contract under which the first use of the water now tapped by its works would be guaranteed to Plainfield and North Plainfield, is considered at some length; and it is stated that it can not well be determined whether such an alternative would prove to the ultimate advantage of the community until it is known what can be done in combining the communities interested for the control of the water supply needed by them and what the cost would be of eliminating the water company from the territory by purchase or condemnation, and, on the other hand, the character and extent of the benefits which would be afforded by a contract with the water company. It is concluded that to combine the communities and directly control the water supply, although requiring much work on the part of the people and their representatives and involving a large expenditure of money would, however, permanently solve the question.

The report of the legal sub-committee, transmitting a communication from Mr. Craig A. Marsh, demonstrates that "the water company may be effectively and permanently removed from the field of competition with the city." The committee recommends a re-submission to the voters of the question of the adoption of the provisions of the statutes whereby the powers necessary to enable the Common Council to adequately handle the situation would be acquired, pointing out that "if the statutes shall become operative it will then be possible for negotiations to be entered upon to ascertain the price at which the water company will sell, and that if no price can be agreed upon, to proceed by condemnation to ascertain by award of commissioners the price for which the works can be acquired in that way." "Condemnation proceedings may be carried far enough to have these questions of what it will cost the city to acquire the water works, finally determined by the proper legal course, so that the figures may be in hand for the consideration of the Common Council in determining the questions which will have to be decided. If then, with all other considerations fully in hand, it shall be found that the contract can be made with greater advantage than to condemn, the condemnation proceedings may be abandoned at any time without prejudice to the city, or if thought desirable, to acquire and operate the works

after full knowledge of the cost, the condemnation may be consummated."

This report was given careful consideration by the Council and the provisions of the act of the legislature entitled "an act to enable cities to supply the inhabitants thereof with pure and wholesome water," approved April 1st, 1876, and the acts amendatory thereof and supplemental thereto, were submitted to the voters and duly assented to by a majority of those who voted either for or against the adoption of these provisions at an election held in Plainfield on the 19th day of April, 1910. By this act the city has acquired the right to acquire the works of the Plainfield-Union Water Company by purchase or condemnation, or to construct new water supply works, as it may deem most advantageous.

Appointment of 1910 Investigation Committee.—The Common Council of Plainfield, deeming it necessary and convenient for the purposes contemplated by the legislative acts referred to, thereupon appointed a special water committee, consisting of Messrs. Frederic E. Mygatt, Francis L. Montgomery, Frank L. Holt, George S. Clay and W. L. Gloak, all members of the Public Affairs Committee of Common Council. The resolution also provided that the committee be authorized and requested to "recommend to Common Council the employment of a thoroughly competent and experienced engineer or engineers to investigate and advise the city with respect to available sources of water supply for said city, the location, and desirability of available lands and rights, that may be acquired by said city by purchase or condemnation proceedings, for the use of said city in connection with the acquiring and establishing of a system of water works, including the lands and water rights now made use of in connection with the water works of the water company now supplying water in said city; to advise the city as to the fair value of such part of the real estate, personal property and works and corporate rights, powers and franchises and provisions of said company last referred to as may be necessary or desirable for the city to acquire by purchase or condemnation; to advise the city as to the cost of purchasing any other available lands and water rights, acquiring any other source of supply, and the construction of water works plant and appurtenances and completely installing the same for the use of said city; and to advise respecting such other matters germane to the foregoing as said committeemen shall deem necessary."

On the 29th of April, 1910, Mr. Mygatt and Mr. Holt, of the Committee, invited the writer to submit a proposition to the Council for acting as its engineer in this investigation. The proposition was accepted by the Council, on the recommenda-

tion of the Committee, and on the 24th of May personal instructions were received from the Mayor, Honorable Charles J. Fisk, and the Council, at a special meeting held at 8 P. M. at which, in addition to the members of the Council, Mr. Craig A. Marsh, Corporation Counsel, was also present.

Contracts Under Which Water is Supplied to Plainfield.

The Plainfield-Union Water Company is now supplying Plainfield with water under a contract, a copy of which will be found in Appendix B, entered into originally May 2nd, 1892. The terms of this contract gave the city the privilege of two renewals, one for one year; in 1902 the contract was renewed for another ten years, expiring May 2nd, 1912.

The only provision in this contract relating to the source of supply is as follows: "said company agrees to supply pure and wholesome water to said city, and the inhabitants thereof on terms, in the manner and at the prices hereinafter stated,——." Nothing is stated in the contract which requires The Plainfield-Union Water Company to furnish water from the Netherwood wells, should the company desire, for any reason, to supply a portion of the water required from other sources. Considerable concern has been felt regarding this possibility, in view of the prospective growth of Plainfield and the other cities which the Plainfield-Union Water Company supplies from Netherwood, and although I understand that the Water Company has verbally given assurance that in case the Netherwood supply were insufficient to supply Plainfield and the communities to the east, the Netherwood water would be reserved for the use of Plainfield and North Plainfield. In November, 1906, in compliance with a request from Mr. Herbert Buxton, Chairman Public Affairs Committee of Plainfield, Mr. Frank Bergen, President of the Plainfield-Union Water Company, drafted a proposed new contract with the water company, in which provision was made to secure to Plainfield and North Plainfield an adequate supply of water at all times from the Netherwood wells, the company reserving the right also "to supply pure and wholesome water in said city from some other source whenever the supply at Netherwood shall become insufficient for the needs of said city and borough and their inhabitants." This contract was not entered into, but an assurance was received from Mr. Bergen April 4, 1908, that the company was still willing to execute the proposed contract if desired by the city. As matters stand now, however, there is no obligation on the part of the company to reserve the Netherwood water exclusively for Plainfield and North Plainfield. During the past summer for a short while the Netherwood supply was so short that not only was it necessary

to pump a portion of the water from the Middlesex Water Company's plant at Robinson's Creek into the Union Water Company's mains through the booster connections at El Mora, but with this added help it was impossible to keep the pressure up to the required amount in the street mains in Plainfield.

The past season has been a particularly hard one on the smaller water supply sources. Since 1893 the quantity of water pumped from the wells annually has increased from 461,000,000 gallons in 1893, to 1,501,000,000 gallons in 1909. In other words, the consumption has increased to more than three times that of 1893 and nearly seven times that of 1892. The conditions of the past summer indicates that in order for the company to be able to enter into a contract such as was proposed in 1906 by Mr. Bergen, an additional supply would have to be provided by the company immediately in order to take care of the consumption to the east of Plainfield regarding which there has been much dissatisfaction in various localities. Apparently the capacity of the Plainfield-Union Water Company's plants supplying water in the district covered by its mains and those of the Middlesex Water Company was about reached during the past summer.

Description of Works from Which Plainfield is Now Supplied With Water.

Location.—The deep wells and pumping station from which Plainfield is now supplied are located at Netherwood Station on the Central Railroad of New Jersey, northeast of Plainfield, in the valley of Cedar Brook. The works have been changed in parts and adapted to changed conditions a number of times, and now have, so far as pumping machinery is concerned, double the capacity of the first installation.

Wells and Pumping Station.—As originally built, the supply works consisted of 20 six-inch tubular wells from 35 to 50 feet deep, located 50 feet apart along a line nearly parallel to and not far from the Central Railroad of New Jersey at Netherwood, and connected together with a suction main varying from 8 inches to 12 inches in diameter, laid about 1 foot above ground, the elevation of which is about 122 feet above sea level, the pump foundation being still higher. Difficulty was experienced at the start, owing to the high suction lift, about 28 feet, and shortly afterwards the suction pipe was lowered 8 feet, so that it was buried some six feet below ground, the pumps being lowered at the same time about 10 feet.

In the fall of 1904, four new 8-inch wells were sunk near North Avenue in a piece of ground 20x300 feet, and one in front of the pumping station, and the 20 original wells were

deepened to 70 feet, one of the wells having been driven to a depth of 300 feet for exploration purposes.

The original pumping plant consisted of two horizontal compound condensing duplex Worthington plunger pumping engines with a capacity of 2,000,000 gallons and 3,000,000 gallons each. About 1904 or 1905 two vertical pumps, one, a Worthington with a capacity of 4,000,000 gallons and the other an R. D. Wood, with a capacity of 6,000,000 gallons daily, were substituted for the original pumps. The new pumps were installed with their water ends at a depth of about 20 feet below ground, the suction main to the wells being lowered to correspond.

The pumps stand in independent wells in the brick pumping station, and a boiler house with stone walls and slate roof contains four 100 H. P. return tubular boilers.

The water is drawn directly from the wells by the pumps and delivered into the stand pipe through a 20-inch interior tube rising 5 feet above the top.

In the early stages of the work Mr. Rudolph Hering was retained as the city's engineer and under his direction pumping tests were made, with a low lift pump, of a number of the main wells then driven, and various other information was collected regarding the direction of flow of the water in the soil and the probable extent of the territory from which the water was being drawn. It was found that the wells on the westerly line yielded more abundantly than the easterly ones under equally good conditions, and gave a lower vacuum for the same quantity pumped. This, taken with the observed condition of water levels tended to confirm the belief that the water came from an underground stream, flowing southwesterly just skirting the eastern wells, and flowing full past the western ones.

The 20 original wells were sunk by the Plainfield Water Works Company, who also partly built the pumping station, but were completed by the Plainfield Water Supply Company, who also laid the street mains and supply pipes and erected the stand pipes, of which there are two, the larger and more important being 25 feet in diameter and 140 feet high and located at the site of the pumping station; the other being 75 feet in diameter and 25 feet high, and located on the mountain to the west of Plainfield. It is connected to the street mains by a 12-inch pipe line about 1,000 feet long, but is not now in service. The elevation of the water in the stand pipe at the pumping station, when full, is 262 feet above sea level. The elevation of the street in front of the fire headquarters in town is about 100 feet above tide water.

Originally there were in Plainfield and North Plainfield

about 30 miles of street mains, but subsequent additions brought the total up to 49 miles in 1905 and a little less than 63 miles in 1910. The lines are laid out and the sizes apportioned with more care and regard for future requirements than was usually the case with water works built during that period and, if the supply could be kept up under extreme conditions, would give fair service as to pressures. The mains range in size from 16 inches to 4 inches in diameter, with a fair percentage of the larger sizes shown in the following table:

6	per cent.	4-in.	diameter.
70	" "	6-in.	"
7	" "	8-in.	"
1	" "	10-in.	"
11	" "	12-in.	"
3	" "	16-in.	"
2	" "	miscellaneous small sizes.	

Fire protection is afforded by some 329 fire hydrants connected to the street mains with 4-inch cast iron pipe, and valves are provided to cut off the hydrants for repairs, as well as to control the flow through the street mains when necessary. Under the contract with the city the company furnishes the corporation cock and goose neck connections, but the consumer furnishes the balance of the service pipe to his property.

Capacity of the Works.—The present pumping capacity at the Netherwood pumping station is nominally 10 million gallons daily, with both pumps running at full rated speed. The capacity of the wells to yield water at high rates for short periods is great. Their true capacity, considering a long series of years will be discussed later. For present purposes it is sufficient to record that for limited times they can and have furnished the pumps with water at rates in excess of 7,000,000 gallons daily, and that for the year 1909 the average rate of draft was over 4,000,000 gallons daily. During the past summer, when the consumption was at its maximum, however, the company was unable to keep up the supply at times.

On the evening of July 26th, the situation having become acute, Mr. Frank Bergen, President of the Plainfield-Union Water Company met with a committee of Council in Plainfield, and during the course of his remarks informed the committee that the City of Plainfield was then using about 6,000,000 gallons of water per day as against 4,000,000 for the same period last year. He stated that the total quantity of water pumped from the ground during the past few days had been at the rate of about 7,000,000 gallons per day, 1,000,000 gallons of this going east as far as Garwood, the other 6,000,000 being used in Plainfield and North Plainfield. He stated that the towns of Cranford, Roselle and Elizabeth were then being supplied from the Robin-

son's Branch pumping station through the booster connection at El Mora, but that there was only about thirty days' water in sight in the Middlesex Water Company's Robinson's Branch reservoir.

He further informed the committee that on the preceding nights the draft had been so great that the water was lowered in the stand pipe 97 feet. As the stand pipe is 140 feet in height the water stood in it but 43 feet in depth, and the pressure in the street mains in front of the Fire Headquarters could not have been over 15 or 20 pounds per square inch. He attributed the large consumption to waste and estimated it to be something like 160 gallons per capita per day. The Mayor and Council were urged, therefore, to appeal to the consumers to prevent the wasting of water, the company being willing as an evidence of its desire to conserve the supply to rebate one-half on the yearly hose rates if consumers would stop using water for sprinkling lawns until further notice.

It had become almost impossible, it was stated, to pump the stand pipe full before three or four o'clock in the morning, the consumption until after midnight being apparently at as great a rate as during the daylight hours.

Improvements Contemplated.—The rapidly increasing population and gradual extension of manufacturing interests in the territory supplied from the Netherwood plant, as well as the other plants in affiliated companies, has for some time past pointed to the necessity of increasing the sources of supply, the pumping facilities and the pipe line capacities at the different works of the company. It has been the idea of the management, I am informed, that it would be advantageous if the different towns in this district could in some way combine their interests so as to secure a supply from the South Branch of the Raritan above High Bridge. An abundant supply could be had from that stream, but the cost of securing it would be too great for any one of the towns, or any one company to assume, and it would only be by joint action that the plan would be rendered feasible financially.

The next best plan, in point of cost, so far as the supply to the different communities supplied by the Plainfield-Union and affiliated water companies is concerned is, so the company considers, to secure a filtered and pumped supply from the North Branch of the Raritan between Raritan and North Branch Station and convey it to the plants to the east to augment their supplies. Some work has been done in this direction, but the refusal of Somerville to permit the Somerville Water Company to lay its 36-inch mains through the streets of the Borough for the purpose of supplying other towns, for fear that the Borough

would thereby become part of a large and complicated water system, has prevented the consummation of the plan.

With respect to the Netherwood plant the improvements now underway include, so far as I am informed, the sinking of ten additional wells to a depth of 300 to 400 feet, to penetrate deeply into the underlying shale rock and secure thus an additional supply from a source independent of that from which the present wells are fed. A considerable force of men has been at work on this improvement for many months and several of the wells have been sunk. Official records of the tests of the wells have not come to my notice, but informally I have been assured that the yield has been large; as high as 425,000 gallons daily per well in some cases; and that it is confidently expected that the 10 wells will yield a total of 4,000,000 gallons daily.

In addition to driving the new wells, the company is constructing a concrete reservoir at this site, with a capacity to hold 500,000 gallons of water, into which the water of the new deep wells will be pumped by an air-lift system. In connection with this system a new triple expansion vertical Worthington pump of 7,000,000 gallons capacity is to be installed, and connections will be made so that this pump, as well as the present 4,000,000 and 6,000,000 gallon pumps can take water either from the reservoir or from the old wells direct, as desired, and pump it to the stand pipe.

In order to further improve the service the company, I am informed, has bought land on the mountain back of Plainfield on which to construct a reservoir.

Adaptability of Netherwood Plant to Plainfield's Needs.

Capacity of Developed Sources.—The probable quantity of water that can be pumped from wells is difficult of estimation owing to the many unknown factors relating to the character of the geological formation from which the water is obtained, such as the porosity of the materials, the sizes of its particles, the sizes of the voids between the particles, the position of the strata, and other controlling influences. These difficulties increase when the area from which the water is collected is indefinite, or when the geological formation is not uniform. Exact results can rarely be expected of such calculations, and they should be used, as a rule, only as guides to judgment based on experience.

The Netherwood wells happen to have been located in a situation where some of the usual indeterminate factors are eliminated and it has been possible, owing to the acute situation developed during the past summer to, in a measure, define the probable safe yield of this group of wells.

The wells are located at Netherwood station, west of and parallel to the tracks of the Central Railroad of New Jersey. They were located there in order to secure water from the gravels and sands along the foot of the terminal moraine, the western edge of which lies to the east of Plainfield, in a line nearly north and south, passing just to the east of the water works station.

Geological Formation.—The bed rock underlying this part of the country is formed of sedimentary shales and sandstones, dipping about 10 to 15 degrees to the northwest. The surface of the rock bed is very irregular, being gouged out in some places and raised up in others to considerable heights. The records of numerous wells that have been dug and drilled throughout this area afford means for showing approximately the general surface characteristics. On the map accompanying this report the rock surface is indicated by contours drawn in dashed lines in the territory east and south of Plainfield, while the contours of the surface of the earth are shown in dotted lines. To the west of Plainfield two parallel ridges rise abruptly forming First and Second Watchung Mountains, having very steep faces on the east, but sloping more gently downward, on their western sides. In the steep easterly faces of these ridges trap rock shows in strata of great depth, with thick beds of shale, and in some places, thin strata of limestone between the beds of trap or diabase.

The melting of the continental ice cap and glaciers produced extensive changes in topography in this district, piling up deposits of boulders, clay, sand and gravel into hills of considerable height, with an irregular surface, full of depressions and sometimes of small connecting valleys.

When the ice melted the overflowing water washed over the edges of the moraine and carried out the clays, sands and gravels, forming the plain, on which Plainfield is situated, stretching down the valley of Green Brook to the Raritan River. As a consequence of this wash the materials underlying this plain are to a considerable extent stratified in layers of more or less porosity, the clays having been largely carried out and washed down the valley of the Raritan while the gravels, sands and boulders were left behind, the coarsest materials being, in general, found near the foot of the moraine.

This plain extends from the moraine to the mountains and reaches from Scotch Plains to South Plainfield. Wells dug or drilled in these deposits have for years yielded an abundant quantity of water. Wells in the moraine itself yield practically no water owing to the mixture of the clay, sand, gravel and

boulders into a mass like concrete when deposited along the path of the receding ice.

Source of Water.—Many suppositions have been made as to the probable source of the water found in the gravels and sands under the plains between the moraine and the mountains, the commonly expressed idea being that it is an underground river flowing in a southwesterly course towards the Raritan River having its headquarters at or near Springfield. While confirming the view that the general natural direction of the movement of the ground water is towards the southwest, as has been observed by the levels of the water in local wells, my observations lead me to the belief that the source of the water is purely local.

The Netherwood pumping station has been in operation since September 1891, and during this period has taken 13,800,000,000 gallons of water from the ground for delivery to the different communities supplied by the company.

In the pumping station there is a 3-inch driven well, extending down deep into the water bearing strata, in which a float, by means of a wire passing over pulleys, indicates the level of the ground water at that point at all times.. This observation well is some 80 feet from the nearest well from which water is pumped, so that its indications do not show the maximum depth to which the water sinks in the pumped wells, but it does show the water level under the same conditions and the daily and monthly range. Daily records of these heights, together with the quantity of water pumped, have been kept at the station since 1891, and a copy of these is given in Appendix B.

A study of these records shows a seasonal and yearly fluctuation of the ground water level, with a tendency towards a failure to recover, entirely, in more recent years as the rate of pumping has increased. This circumstance has attracted the attention of the city officials and has caused uneasiness growing out of the fear that the sources were becoming permanently exhausted, due to the emptying of the basin in which the water bearing strata lie.

All the ground water in this region finds its source in the rain falling on such portions of the earth's surface as deliver their percolating waters into the basin between the trap rock outcrops of the Watchung Hills and the edge of the terminal moraine to the east of Plainfield. Very little of the water percolating into the ground in Washington Valley, between First and Second Mountain, finds its way into the gravel filled basin under Plainfield owing to the dip of the strata, and the terminal moraine is so nearly impervious to water that a large percentage of the rainfall thereon either collects in pools and small lakes,

runs off in the streams during storms or is held and absorbed at the surface by vegetation, so that the visible watershed from which the water would naturally seem to come would be practically limited to the area of the plain, between the moraine on the east and the mountains on the west, unless the hypothesis of an underground river flowing southwest from the neighborhood of Springfield were established.

The principal facts which would indicate the improbability of this are, first, that the moraine itself, which lies up against the mountain above Scotch Plains, is practically non-pervious and would tend to cut off any flow from the direction named; second, that the ground level at Springfield is practically the same as that at Plainfield, and hence there would be no slope available to cause the ground water to flow towards Plainfield; and third, that the distance from Springfield to tide water at Newark Bay is much less than the distance from Springfield to the Raritan River south of Plainfield, and the natural course for the ground water would be along the line of least resistance to tidewater.

The water tightness of the soil of the moraine is shown by the records of wells driven therein; practically none of these, as can be seen by reference to the map and the list of wells in Appendix B, yielded water until they had penetrated through the moraine deposits and entered the shale or sandstone rock below.

A still further confirmation of this view is had in the records of the yields of the Netherwood wells and the corresponding water levels as recorded at the pumping station.

Limit of Yield.—An examination of these records will show that the ground water level rises and falls rythmically with the variation in rainfall distribution and the pumpage. An inspection of the ground-water level records will show times when, starting from a given elevation, much below its natural normal, the water level will rise and then gradually fall again to the same or a lower level. Assuming that under the above conditions it rises to a certain height and then falls again to just the original height, it may be assumed that the rising was due to an accession of ground flow, due to rainfall, and the falling to its being pumped out again. If, under these conditions, the annual rainfall, the percentage of this that reached the water bearing strata, and the rate of pumping be known, it should be possible to ascertain the area of land surface from which the water was derived.

Several calculations of this sort, by approximation, have been made, from which it appears that one square mile of this area can sustain through a long dry period a draft of about 764,000 gallons of water per day, which would be equivalent

to a depth of 16 inches of rainfall per year on each square mile. Drafts as high as 1,320,000 gallons per square mile, equivalent to 27.8 inches per year on the watershed have been customary at this plant, and it has only been by virtue of a succession of years of well distributed rainfall that the wells have responded so well as they have to the drafts made on them.

These figures may be tested in the manner given in Figure 4, in which the full back line shows the observed height of the water in the well at the pumping station from December, 1897, to November, 1899, and a dotted line the calculated height of the water with an assumed draft of 1,340,000 gallons per square mile per day from 1.2 square miles of watershed, based on the monthly rainfalls of previous months, on the evaporation and percolation losses determined from the Croton and Passaic and on an allowance for storm floods of 10% of the difference between the rainfall and the evaporation. The calculated curve for ground water heights is plotted on the assumption that the soil has 10% of effective voids in which the water can be contained.

A similar test for the period between January, 1894, and April, 1895, is shown in Figure 5. In this case the draft per square mile is assumed the same as before, and the necessary area to yield the required quantity of water was 1.54 square miles.

A still further test is given for the period from January, 1908, to June, 1910, in Figure 6. Here the draft is still maintained at the rate of 1,340,000 gallons per square mile per day, and the area necessary to supply the water has been increased to 3.4 square miles.

The principal points of interest in these figures are: they indicate that, when a long period of time is considered, this soil can not supply water to the present plant at a much greater rate than about 1,300,000 gallons per square mile per day; that, apparently the water cannot get to the pumps, from an area much in excess of about 3.5 square miles, and that, drawing from this area, the pumps would take out all the available water resulting from the rainfall and then draw water out of the soil-storage at a rate to cause the water level in the soil to fall at the same rate over the available area as the existing ground water level has actually fallen.

By pursuing this line of investigation further, it can be shown that with rainfall conditions as they were from 1878 to 1881, a draft of about 760,000 gallons per square mile or about 16 inches of rainfall per year per square mile of the available watershed, would have been the maximum possible without progressively lowering the ground water level. The pres-

ent rate of draft on this same area is about 28 inches per year. If, during the period referred to, the draft by the pumps had been at as great a rate as at present, the water would have been pulled down, if the wells could have been lowered enough and the depth of the water bearing strata would have permitted, many feet below the bottoms of the present wells. There has only been one period of two successive years when the rainfall conditions would have maintained the supply of water, at the present rate of draft, without a lowering of the ground water level.

The practical deductions to be drawn from these studies are:

1. The source from which the Netherwood wells derive their supply is local and from 3 to 4 square miles in effective superficial area.

2. The capacity of the watershed to yield water continuously to the present works is limited and has been reached and exceeded for several years, with the consequent gradual progressive lowering of the level of the ground water.

3. The lowering of the ground water level is not permanent, as it will recover partly, with accession of more water during the winter and spring, and, may, even with the present heavy draft, recover materially, under favorable conditions.

4. The plant, for a few months at a time, can yield water at rates much higher than the average permissible rate; rates as high as 7,000,000 gallons a day having been reached during the past summer.

5. Under unfavorable rainfall conditions, such as existed from 1878 to 1885, the permissible draft to avoid exhausting the sources, would have been at a rate of not over 2,600,000 gallons daily from the plant.

6. Under usual or normal conditions, during a long period of time, it is probable that about 4,000,000 gallons per day would represent the average available supply with a fair chance of complete recovery of level after periods of depletion.

7. All the available water in these stratified glacial wash deposits cannot be secured by this one plant; some of the water far away will not run to the plant and hence cannot be collected there.

8. If an additional supply from these deposits is desired, it must be collected from an additional separate plant.

9. Driving more wells into the gravel in the neighborhood of the old wells will not increase the supply as the present wells will permit lowering the ground water level, and more wells would only increase this effect by securing a temporary additional rate of supply for a short time; the capacity of the plant is limited by the rate at which the water will run to the wells through the gravel layers.

10. An additional supply at the site of this plant can only be secured in case a separate and distinct source can be tapped by sinking the wells down into the rock and finding water in crevices and in the pores of the sandstone and shale rocks not connected in any way with the water

in the overlying gravel. This has been done, and the results, so far as they have been brought to my attention, seem promising. Mention has been made of this in previous pages.

11. As the well plant stands, therefore, (not counting the new deeper wells), it has not more than sufficient capacity for the needs of Plainfield alone at the present time. As a matter of fact, even with the help of the El Mora station this summer, it was not possible to keep up the pressure in Plainfield, with every practicable restriction in force to avoid wastage of the water.

12. If the new deep well plant proves to have as great a capacity as anticipated, viz.: 4,000,000 gallons daily, (and I see no reason why it should not, if the wells be properly located), the entire plant, source of supply and pumping machinery would be just about sufficient to care for the needs of Plainfield and North Plainfield for the next 25 to 30 years, providing none of the water be taken to the east, and providing that a distributing reservoir of from 4,000,000 to 8,000,000 gallons capacity be added to the system to balance the fluctuations in draft. In the meantime, of course, a part of the ground water could, without injuriously affecting Plainfield, be delivered to the communities to the east, and as their population increases, additional sources of supply would have to be developed to take care of their consumption, reserving the Netherwood supply for Plainfield and North Plainfield. Whether or not the company would anticipate the needs of this growth sufficiently far in advance to avoid embarrassment to Plainfield is a question that does not admit of answer at this time.

Quality of Present Supply.—The quality of the water furnished by the Netherwood plant is excellent in all respects, except that its hardness is too high to be satisfactory for boiler purposes, bathing and laundry uses. It is not as hard as the waters, for instance, of Toledo and Columbus, Ohio; Philadelphia, St. Paul or Minneapolis, yet it would be improved materially by softening.

The water from the new deep wells is said to be somewhat harder than the old supply.

The Distribution System in Plainfield.

Extent and Value.—The absence of precise data as to the amounts of pipe laid in Plainfield each year renders it difficult to estimate accurately the depreciation of the different parts of the works, so far as this is dependent upon their age. The oldest pipes in use in Plainfield were laid in 1892 and are consequently 18 years old. Since 1892 extensions have been made from time to time which have increased the original 30 miles of pipe, including that in North Plainfield, to 49 miles in 1905, and to about 63 miles in 1910.

The amounts of the different sizes now in use are given in Table X.

TABLE X.

Plainfield.		North Plainfield.
16-in. pipe........	10,660 lin. ft.	....
12-in. pipe........	25,550 lin. ft.	 12,225
10-in. pipe........	2,724 lin. ft.	....
8-in. pipe........	16,050 lin. ft.	 5,050
6-in. pipe........	187,000 lin. ft.	 46,600
4-in. pipe........	17,700 lin. ft.	 1,000
Miscell.............	6,250 lin. ft.	 1,000
Valves	166	 128
Hydrants	329	 89

The above data have been taken from the map compiled in the office of Mr. Andrew J. Gavett, City Engineer and Street Commissioner of Plainfield. The estimated cost of duplicating the mains in Plainfield at present prices for materials and labor is given in Table XIV. following; the prices include the cost of special castings, valves, connections to mains and repairing street pavements.

In the following table of unit costs, current prices for materials delivered on the ground have been used. The cost, above the cost of the pipe alone, for the special castings used is based on the allowances given in Table XI.

TABLE XI.

Estimated Weight of Special Castings per Foot of Pipe Laid.

4-inch pipe......................	0.6	lb. per lin. ft. of pipe.
6- " "	0.7	" " " " " "
8- " "	0.9	" " " " " "
10- " "	1.2	" " " " " "
12- " "	1.8	" " " " " "
16- " "	3.1	" " " " " "

Special castings have been estimated at a cost of 2.4 cents per pound.

The cost of valves per foot of pipe has been based on a count of the valves of different sizes, in the pipe lines, and distributing their cost pro rata, to the pipes in which they occur.

The cost of corporation cocks and lead connections has been based on an estimated number of 4,000 such connections in Plainfield, and the cost distributed pro rata to the different pipes.

It is assumed, in making the estimates, that to place the pipes in the ground anew it would be necessary to replace, in first-class condition, all street pavements interfered with, and hence there is added to the cost per foot of each size pipe 14.6 cents to cover this item. This was arrived at by estimating the total lengths of streets and street intersections where pavements would have to be taken up in relaying the pipes in the streets of Plainfield; the totals are given in Table XII.

TABLE XII.

Cost of Repaving Water Main Trenches in Plainfield.

Kind of Pavement	Lineal feet of trenches in			Sq. Yards of Pave-ment.	Cost per Sq. Yard.	Total Cost.
	Streets	Inter-sect'ns.	Total.			
Brick	4,050	100	4,150	1,383	$2.00	$ 2,766.00
Telford	12,980	740	13,720	4,573	1.75	8,002.00
Macadam ..	44,030	10,420	54,450	18,150	1.50	27,225.00
Totals	61,060	11,260	72,320	24,106		$37,993.00

Total lineal feet of street mains, 259,684.
Average cost of replacing pavements, $0.146 per lineal foot.

Based on the foregoing data and on fair costs for labor, the costs per lineal foot of trench, of providing and laying street mains in Plainfield at the present time, would be as given in Table XIII, (Page 49.)

The street mains now in use in Plainfield are of different ages, some having been laid in 1891, and others, as needed, between that year and the present. Figures showing the exact amount laid each year have not been furnished to me, and only general statements are available. There is now more than twice as much pipe in the ground as at the end of 1892.

In the 13 years from 1892 to 1905 there were added about 19 miles of pipe; in the five years from 1905 to 1910, 14 more miles were added. The rate of increase, therefore, has been more rapid in recent years. Approximately about half the pipe is 18 years old; about one-third is between 5 and 18 years old; about one-fifth is less than 5 years old. A fair statement of the condition, therefore, would be the assumption that half the pipe is 18 years old; one-third is 11 years old; one fourth is 2 years old.

The life of cast iron pipe, under fair conditions, is customarily assumed to be from 75 to 100 years unless special conditions, such as electrolysis, heavy incrustation, or exceptional corrosion, due to soil and moisture conditions, cause more rapid deterioration.

Inquiry among local plumbers failed to bring to light evidences of troubles of this sort in the street mains, although service pipes have in some cases shown it. The general experience has been that the street mains are reasonably clean, not incrusted sufficiently to materially impair their capacities and generally in good condition. Extraordinary depreciation, therefore, can be eliminated and the expected future life of the pipes be assumed to fall in line with average experience.

The depreciation due to age can be figured on two bases,

DIAGRAMS SHOWING
ACTUAL AND COMPUTED HEIGHTS OF WATER IN
WELLS AT NETHERWOOD PUMPING STATION OF THE
PLAINFIELD-UNION WATER SUPPLY CO
ACTUAL HEIGHTS SHOWN IN FULL LINES AND COMPUTED HEIGHTS IN DOTTED LINES

FIGURE NO. 4

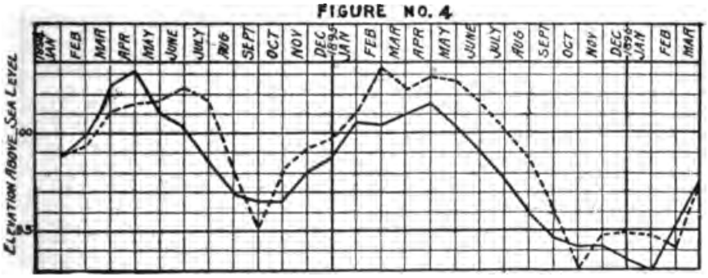
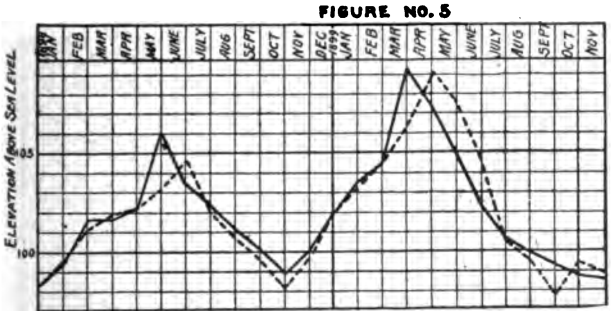


FIGURE NO. 5



To accompany a Report on the Water Supply of Plainfield, N.J. by James H. Fuertes, C.E. New-York, Nov. 1910.

FIGURE NO. 6

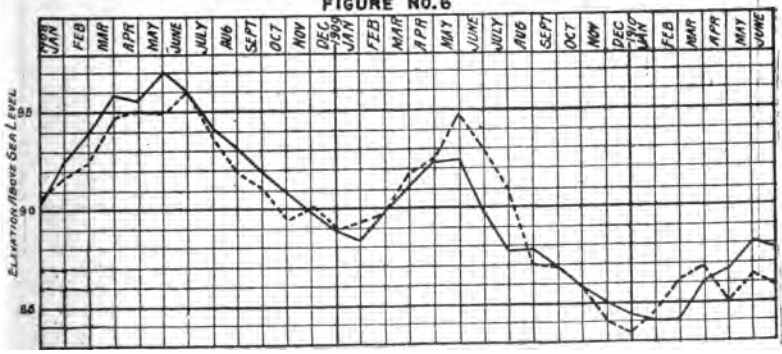


TABLE XIII.

Estimates of Cost per lineal foot of Cast Iron Water Mains laid in Streets of Plainfield, N. J., 1910.

Size of Pipe.	4-in.	6-in.	8-in.	10-in.	12-in.	16-in.
Cost of pipe per ton.	$24.20	$23.40	$23.05	$22.90	$22.90	$22.90
Weight of pipe per foot; lbs.	20	30.8	42.9	57.1	72.5	125
Weight of yarn per ft. of pipe.	.017	.025	.033	.042	.050	.070
Weight of lead per ft. of pipe.	.67	1.00	1.33	1.67	2.00	2.67

Costs Per Foot.

Cast iron pipe.	$0.242	$0.360	$0.494	$0.654	$0.830	$1.430
Yarn, at 6¼c	0.001	0.002	0.002	0.003	0.003	0.004
Lead, at 4½c.	0.030	0.045	0.060	0.075	0.090	0.128
Caulking	0.012	0.015	0.018	0.021	0.025	0.050
Cartage	0.010	0.015	0.023	0.030	0.038	0.063
Trenching, etc.	0.086	0.097	0.112	0.127	0.143	0.180
Tools and superintendence	0.038	0.053	0.071	0.091	0.113	0.185
Specials	0.014	0.016	0.021	0.028	0.053	0.074
Valves	0.006	0.007	0.017	0.017	0.027	0.043
Taps and connections	0.023	0.023	0.023	0.023	0.023	0.023
Repairing Pavements	0.146	0.146	0.146	0.146	0.146	0.146
Total	0.608	0.779	0.987	1.215	1.491	2.326
15 per cent.	0.091	0.116	0.148	0.182	0.224	0.349
Total cost per ft.	0.699	0.895	1.135	1.397	1.715	2.675
Prices used	.70	.90	1.14	1.40	1.71	2.67

one assuming that the loss of value is directly proportional to the age and the other that this depreciation can be more economically taken care of by establishing a fixed yearly payment to a fund, kept reinvested and earning interest, the payment being adjusted by principal and interest, to equal the cost of the

mains in, say 80 years. This method is fair when sufficient data are available to use it. The uncertainty in the present case is that the rate of interest which the annuity would earn, if reinvested in the company's plant, would be indeterminate, and the exact years during which each separate extension was made can not be ascertained at present.

In view of these uncertainties it would seem an unnecessary refinement, for present purposes, to work out a statement of the present value of the pipes involving annuity payments and I have, therefore, assumed a reduction in value proportionate to an assumed average life of ten years for the entire system as being probably as near the correct amount as can be estimated at the present time, with the data at hand. On this basis the loss in value of the mains, assuming a life of 80 years, would be one-eighth of their reproduction cost and of the hydrants, valves, etc., about one-fourth of their cost assuming that these latter parts would give an effective service, on the average of about 40 years.

The estimated present physical value of the street mains in Plainfield, including the 16-inch force main from the Netherwood pumping station to the connection with the Plainfield mains, but not including the value of the stand pipes, the mains in North Plainfield or the wells and pumping plant is as given in Table XIV.

TABLE XIV.

Present Value of Water Mains in Plainfield, including Valves, Connections to Mains, Fire Hydrants, and Special Castings, an Allowance being made for depreciation.

17,700 lin. feet of 4-in. pipe at $0.70		$ 12,390.00
187,000 " " " 6-in. " at 0.90		168,300.00
16,050 " " " 8-in. " at 1.14		18,297.00
2,724 " " " 10-in. " at 1.40		3,813.60
25,550 " " " 12-in. " at 1.71		43,690.50
10,660 " " " 16-in. " at 2.67		28,462.20
		$274,953.30
329 Hydrants, in place, at $35.00		11,515.00
Total		$286,458.30
Depreciation on street mains, $263,738.00, at 12.5 per cent	$32,967.25	
Depreciation on valves, hydrants, etc., $22,730, at 25 per cent	5,682.50—	38,649.75
Estimated net physical value of street mains and accessories in Plainfield		$247,818.55

The Acquisition of the Water Supply Works of the Plainfield-Union Water Company By the City of Plainfield.

Franchise Rights.—In all cases where the purchase or condemnation of the whole or parts of plants of this nature are involved questions of franchise rights and going-concern values,

apart from the physical value of the plant, require consideration. In this connection I applied to the Chairman of the Special Water Committee, Mr. Frederic E. Mygatt, for information as to the local rights of the Plainfield-Union Water Company and the legal requirements that would have to be observed in valuing the Water Company's properties in Plainfield in order to place the present water supply works on a fair basis for comparison with other methods by which Plainfield might secure an ample and suitable water supply. My application was referred by Mr. Mygatt to Mr. Craig A. Marsh, Corporation Counsel, and his reply, which concisely and lucidly states the mutual relations of the city and the Water Company is given herein in full.

Plainfield, N. J., Oct. 14, 1910.

Frederic E. Mygatt, Esq.,
Chairman, Public Affairs Committee,
Plainfield, N. J.

Dear Sir:—

I have your letter of the 13th inst. enclosing copy of questions submitted to you by Mr. James H. Fuertes.

The several questions are quoted from Mr. Fuertes' letter, and my answers appear under the several questions respectively:

Question:

"(1) Could the City of Plainfield parallel the water mains of the Plainfield-Union Water Company, and thus gradually acquire the business of the Plainfield-Union Water Company, without being compelled to compensate the Plainfield-Union Water Company for the loss of its business in Plainfield?"

Answer: Yes.

Question:

"(2) If the City of Plainfield should build an independent water works and lay independent street mains in Plainfield and supply the inhabitants of Plainfield with water without interfering with the sources of supply used by the Plainfield-Union Water Company, would the Plainfield-Union Water Company have a right to claim compensation for the loss of its business and property in Plainfield when all the water consumers attached to the mains of the Plainfield-Union Water Company shall have left that company and have attached their properties to the municipal water mains?"

Answer: No.

Question:

"(3) Assuming that the City of Plainfield should establish a municipal water plant and should desire to purchase the water mains of the Plainfield-Union Water Company in Plainfield, but not the sources of supply or the pumping plant at Netherwood, would it be necessary to com-

pensate the Plainfield-Union Water Company for the loss of business in Plainfield and for the going-value of this business, as well as for the cost of the street mains themselves; or, is their franchise in Plainfield of such a nature that they would have no claim to compensation for the loss of the Plainfield business providing they were paid a fair value for the street mains?"

Answer:

If the city should purchase the water mains of the Plainfield-Union Water Company as suggested in the question, all it would have to pay would be the purchase price, which, of course, as in all cases of purchase, would be arrived at by agreement of the parties.

Assuming, however that the question is meant to apply to the case of condemning the water mains, etc., as distinguished from their purchase, I answer further that, while in that case the commissioners would not be required to award compensation for the loss of business and for the going-value of the business, yet they would be required to consider as an element of the compensation the damage which would result to the Water Company from the taking of the water mains in question, their duty being to make a just and equitable appraisement of the value of the property taken and assessment of the amount to be paid by the city for the property and the damages. To illustrate, if the property taken were part of a tract of land on which was a dwelling-house, the commissioners would be required to take into consideration the injury to the lands and to the owner's dwelling-house on the estate, and the deteriorations of his lands for agricultural purposes or for building purposes. See, **Somerville &c. R. Co. V. Doughty. 2 Zab. 295.** Of course, if merely the present water mains of the company were condemned, thereby leaving the Water Company the right to put in new mains in the place of the old, the commissioners would be required to take that fact into consideration also.

Question:

"(4) Assuming that the City of Plainfield desired to purchase not only the street mains, but the sources of supply and the pumping plant at Netherwood, and reserve all the water for Plainfield's future growth, would it be necessary for Plainfield to pay, in addition to the physical value of the street mains and pumping plant, a sum to compensate the Plainfield-Union Water Company for the value of its right to do business in Plainfield and in all the other towns supplied by the Plainfield-Union Water Company from the Netherwood plant? It has, in the past, been the custom for the Plainfield-Union Water Company to deliver water from the Netherwood source to consumers as far east as Elizabeth, and if the city purchased the plant and should need all the water which the plant could produce so that there would be none left for the consumers

to the east of Plainfield, could the obligations of the Plainfield-Union Water Company to supply these cities with water for the basis of claims which Plainfield would have to satisfy if it took by condemnation the works at Netherwood?"

Answer:

The commissioners in the case supposed in the question would, undoubtedly, be required to award just compensation, not merely for the physical value of the street mains and pumping plant, but for the value of the franchises taken. The public can no more condemn the franchises of a corporation for public use, without making compensation, than the public can take lands, houses or pipes of a corporation without making compensation. The Water Company would be entitled to be compensated for the damages sustained in consequence of the taking, including the right of the company to take water from within the city to be conveyed by pipes to points to which the company has the right to convey such water. Of course, many other elements would enter into the question of the amount to be awarded by the commissioners, as, for example, the right of individuals to organize a new water company, to take water from beneath the surface of Plainfield's territory, and convey it beyond the city limits, and sell it, under **Gen. Stat. 2999, pl. 352, and the Supplement, Gen. Stat. 2202, pl. 369**; the adequacy of the supply beneath the surface of Plainfield's territory; the right of the city to draw from the same source of supply, a right fully equal to that of the Water Company; the right of property owners, whose wells or natural water courses are or may be injured by the action of the Water Company in improperly drawing upon the underground water supply, to obtain injunction and damages against the Water Company, under the Court of Errors and Appeals' decision in **Meeker v. East Orange, 74 Atl. 379.**

If the city should purchase or condemn the Water Company's plant and franchises, the city would also come within the ruling in **Meeker v. East Orange**, just cited, that case having decided that it was unlawful for the City of East Orange to withdraw underground waters for distribution or sale for uses not connected with any beneficial ownership or enjoyment of the lands whence the waters are taken, if it thereby result that the owner of adjacent or neighboring land is interfered with in his right to the reasonable user of sub-surface water upon his lands, or if his wells, springs or streams are thereby materially diminished in value, or his land rendered so arid as to be less valuable for agriculture, pasturage or other legitimate uses, and that such an injured property owner was entitled to recover damages against the city.

Question:

"(5) Is there any value attached solely to the privilege of putting water mains in the streets of Plainfield, apart from that growing out of or implied by the right of the company to sell water in Plainfield?"

Answer:

Yes, the charter rights of the companies, which subsequently merged and consolidated into the present Plainfield-Union Water Company, gave those companies, respectively, the franchises of putting water mains in the streets of Plainfield for the purpose of supplying water, not only within the corporate limits of the city, but beyond such limits.

Question:

"(6) As franchise rights, per se, are usually valued on the basis of their net earning power, and the going-value of plants on their incomes and expenses, and as the Plainfield-Union Water Company would probably refuse to give access to the books of the company for the ascertainment of these items, are there any circumstances in connection with the charter of the water company and its component companies, or their contracts with Plainfield or the other municipalities which would operate to extinguish, or off-set the franchise value in Plainfield considered apart from revenues?"

Answer:

The act prescribing the duties of commissioners in condemnation proceedings in New Jersey is **P. L. 1900 p. 79,** and provides that a Supreme Court Justice "shall appoint under his hand three disinterested freeholders, residents of the county where the land or property to be taken lies, commissioners to examine and appraise the said land or property" and to assess the damages on at least six days' notice. The next section directs that the commissioners, after being duly sworn, &c., "shall meet at the time and place appointed and proceed to view and examine the land or other property, and to make a just and equitable appraisement of the value of the same, and an assessment of the amount to be paid by the petitioner for such land or other property and damage aforesaid, as of the date of the filing of the petition and order thereon."

The Constitution provides that "Private property shall not be taken for public use without just compensation;" (See, Art. I, par. 16), and also expressly provides as follows:

"8. Individuals or private corporations shall not be authorized to take private property for public use, without just compensation first made to the owners." Art. IV. sec. VIII, par. 8.

I know of no special law in New Jersey under which the franchise rights of the company could be valued. Indeed, under the Constitutional provisions just quoted, it is not within

the power of the Legislature to fix the compensation, or determine in what it shall consist, or prescribe the rules or principles upon which it shall be computed. See, Lewis on Eminent Domain, 3d Ed. sec. 683.

The general rule regarding compensation to the property owner is, that the compensation should be precisely commensurate with the injury sustained by having the property taken, or, as elsewhere expressed, "just compensation means that the property owner shall have a fair equivalent in money for the injury done him by the taking of his property." Upon condemnation proceedings being taken, there can be little doubt of the power to gain access to any books of the company necessary to enable the commissioners to perform their duties.

I know of no circumstances in connection with the charter of the Water Company and its component companies, or their contracts with Plainfield or the other municipalities inquired about in the question, other than those already indicated in the answers to the preceding questions.

Yours truly,

(Signed) CRAIG A. MARSH.

Relations of Plainfield-Union Water Company to Plainfield.—There are several aspects in which the property of the Plainfield Water Supply Company must be considered in relation to Plainfield needs.

1st. The conditions under which the company would continue to supply Plainfield in the future, in which case there would be no question of purchase or condemnation of the company's works in whole or in part, the question being one of executing a contract agreeable to both parties.

2nd. The conditions under which the City of Plainfield would supply itself with water, in which case there would be involved:

a.—The provision of a new source of supply with new street mains, etc., leaving the company in possession of its entire plant and franchises.

b.—The provision of a new source of supply, combined with purchasing or condemning the street mains and accessories, but leaving the company in possession of its source of supply and pumping station.

c.—The acquisition by purchase or condemnation of the street mains, sources of supply and pumping station of the company in Plainfield, leaving it in possession of its pipes, etc., outside of Plainfield.

Under Case 1., no questions of valuation arises unless a readjustment of the rates be sought.

This question, I believe, is not under discussion, previous committees having reported that the rates are not excessive.

Under Case 2., if I properly understand Mr. Marsh's opinions, quoted above, questions of the valuation of franchise rights

and going concern value do not enter under division "a." Under division "b" it would be necessary to consider, in case the street mains were condemned, the damages that would result to the company from the taking of their mains. This will, of course, involve questions of valuation and compensation for loss of property and business if the company's franchises are condemned. If merely the present water mains of the company were taken, leaving the company the right to put in new mains instead of the old, the measure of the injury to the company would be smaller. Under division "c" questions of the present value of the physical property as well as the value of the company's franchises in Plainfield and all the other communities supplied by the company from this source and through these mains, now and in the future, as well as compensation for the cost of developing the income enjoyed by the company that would be affected by the taking would require ascertainment, and this without doubt would have to pass through court proceedings for final adjustment.

In view of the impossibility of securing full knowledge of the details of the company's expenses, revenues and obligations of all kinds, to put a valuation on the franchises and rights of the company would be only guess work and hence no definite statements on this subject are made herein.

Acquisition of Street Mains.—In a general way it may be stated that the condemnation of the street mains in Plainfield only, leaving the company the right to build new mains, if it so desires, would require only payment for the mains, and accessories at a fair valuation.

The right which the city has to lay its own water mains, as though there were no water company's mains now in the streets, would fix the ultimate reasonable compensation for the mains at the cost of laying the same mains anew and acquiring the business which grows out of the ownership of the mains, less an amount representing the depreciation of the property through age. If a higher award than this were demanded, the city's reply would be to lay its own mains. The cost of acquiring the business, after laying the new street mains, would consist of the cost of connecting the consumers' service pipes to the new mains and the proportionate part of the maintenance expenses and the fixed charges on the cost of the works that would have to be carried until the business now done by the Water Company could be acquired by the city; this might require five or six years or more to accomplish and its exact present-value in money could only be estimated from a detailed knowledge of the cost of operating the company's works.

Without having the figures at hand, however, it would,

in my judgment, be fair to assume that the total cost of acquiring this business, spread out over a number of years would not, in this case, exceed the amount deducted from the estimated reproduction cost of the mains for depreciation, so that in this particular instance the reproduction cost of the mains and accessories, disregarding depreciation, could be fairly considered the present value in case either the city should lay its own mains or condemn those of the present company.

Impracticability of Acquisition of Netherwood Source of Supply.—With regard to the purchase or condemnation of the company's sources of supply at Netherwood and its pumping station and supply works, however, the company's franchise rights will be very valuable owing to the effect which the taking of the sources of supply might have on the obligations of the company to other municipalities as well as Plainfield, and the ascertainment of this franchise valuation, unless the company was a willing seller to the city, would be impossible except through court proceedings. Speculation as to the present value of these franchises along these lines would be valueless and I, therefore, make no approximation of the value of such rights. Suffice it to say that, as other sources of supply are available, at construction costs, (for equal service), no greater than would be the cost of the present works, I should feel that under no circumstances would it be desirable for the city to attempt to purchase the Netherwood plant unless the Water Company was desirous of selling and would sell out at a figure no higher than a fair reproduction cost of the physical plant. This, owing to the obligations of the company cannot reasonably be expected and hence I reach the conclusion that if Plainfield is to have a new municipal water supply plant, the water will have to be secured elsewhere than in the neighborhood of the Netherwood plant of the Plainfield-Union Water Company.

PART IV.

Gravity Supply from Lamington River,

Topography and Geology.—The highlands of New Jersey, lying to the north and west of Plainfield, offer opportunities for storing water on the branches of the Raritan River. Several of these sites lie at a sufficiently high elevation to permit of delivering the water to a high-service distributing reservoir near Plainfield by gravity. Of these sites special mention here will be made of but two, as at all the other available sites the expense of securing the water would be greater than from either of the two especially mentioned, and the likelihood of costs for extinguishment of water power rights would certainly be no less than in the case of the two sites herein specifically mentioned.

The two streams which offer the most advantageous opportunities for gravity supplies are the Lamington River and the North branch of the Raritan River.

Location for Dam.—At a point about a mile below Hacklebarney, on the Black or Lamington River, there is an excellent site for the erection of a dam. Above this point the Black River drains about 26.85 square miles of the New Jersey highlands. The river flows through a narrow valley with a level bottom varying from ¼ mile to a little over a mile in width. During the wet season these bottom lands are overflowed and converted into a marsh, or swamp, some 5 miles in length. It is in this portion of the valley that the water acquires the color, which gave rise to the local appellation of "Black River." The watershed of the stream is quite well timbered, and the rainfall and stream flow conditions are about normal for this portion of the Atlantic seaboard.

Population on the Watershed.—The watershed, with the exception of the small settlements at Kenvil, Succasunna and Chester, has a rather sparse rural population. Kenvil and Succassuna lie at the extreme northern portion of the watershed. The total population on the watershed I estimate to be not over 1200 or 1500 people, of which the larger portion reside in the villages of Chester and Succasunna. Chester lies on top of the mountain, on the east side of the watershed, and the drainage therefrom finds its way principally into branches of Peapack Brook which empties into the North branch of the Raritan River above Far Hills. It is my judgment that not over about a thousand people should be considered as resident upon the watershed of the river above the proposed dam site or about 37 people per square mile of watershed. Some years ago the population of this district was much larger than at present, the maximum having been reached about 1885 when the iron mines were extensively worked. The present population, judging from the census returns of the townships within which this watershed lies, is probably about the same as it was in 1850, and there is very little likelihood that conditions will change in the future in such a manner as to increase materially the population resident on the watershed above Hacklebarney. The population per square mile resident upon this watershed is considerably less than upon the Croton watershed above the old Croton dam, and about the same as on the Bronx and Byram Rivers, the Croton, Bronx and Byram being the sources from which New York City derives its water supply.

Although the little settlements of Succasunna and Kenvil and also several farm houses and mines are located along or near the main stream and its branches, the pollution arising

from such sources could be easily controlled and the water after storage in the proposed Hacklebarney reservoir would be as safe and satisfactory as the better run of gravity water supplies.

It is considered that a simple form of mechanical filtration would be desirable in connection with this supply, as there would possibly be short periods during the spring floods when the water in the reservoir would be rendered somewhat turbid. The quality of the water, further, can be rendered perfectly safe against accidental dangerous pollution by adopting the treatment in use at the Boonton reservoir of the East Jersey Water Company, which will be referred to later.

Quantity of Water Available and Storage Required.—The site chosen as suitable for a storage reservoir is in a narrow gorge about a mile and a half below the Hacklebarney mines, at which point a masonry or concrete dam could be constructed. By building the dam 110 feet in height, requiring the purchase of about 100 acres of land, a yield of 8,000,000 gallons per day could be had from this watershed; by building the dam 90 feet high, the storage provided would give a yield of a little under 6,000,000 gallons daily in the driest seasons. The data for the calculation of the yield of this reservoir are as follows:

Drainage area above dam site....	26.85	square miles.
Area of reservoir full (elevation of water surface 600).......	0.0674	" "
Area of reservoir drawn down to elevation 560..............	0.0211	" "
Average area of water surface....	0.048	" "
Net area of land surface.........	26.80	" "
Percentage of water surface to entire watershed area........	0.8	per cent.

The storage capacity of reservoir between elevations 560 and 600, would be 353,000,000 gallons, or 13.18 million gallons of available storage per square mile of entire watershed.

The yield of the watershed would be 200,000 gallons per square mile per day, giving a total continuous yield of 5,700,000 gallons daily from the reservoir.

Similar calculations with the crest of the dam at elevation 624 feet above sea level indicate that the storage available at that elevation (808,000,000 gallons) would make possible a yield of 8,000,000 gallons per day from this reservoir. The data upon which these yields are calculated have been taken from Figure 3, which has been prepared from the records of the annual measured yields of the Croton River supplying New York City and the Sudbury forming a part of Boston's supply. The data given in the diagram represent, in my judgment, the safe yields that may be expected from these New Jersey streams under local conditions.

The proposed impounding reservoir if built to yield

8,000,000 gallons per day during the driest weather would cover 70 acres; if built to yield 6,000,000 gallons per day the stored water would flood about 45 acres.

It is to be understood that the yields above mentioned are those which can be depended upon through a long series of dry years; ordinarily the reservoirs mentioned will supply very much larger quantities of water continuously. In making estimates of cost, however, the most extreme conditions should be assumed, and the data used in figuring the yields and cost of development of the plants suggested as possible are based upon the assumption that the plants proposed will yield continuously the quantities of water stated through long periods of drought as severe as any of which records have been had in this part of the United States since 1868.

Quality of Water.—The quality of the water that will be supplied from this reservoir will be excellent, being soft, practically free from constituents which would cause hard scale to form in boilers, low in organic matter, and free from bacteria and evidences of surface drainage. A small amount of color is acquired by the water in passing through the marsh lands in the valley above Hacklebarney. The color noted in the analysis of this water in Appendix C of the sample collected September 16th, 1910, viz: 17, (on the platinum cobalt scale) is higher than would ever be experienced in case the water should be stored in the larger reservoir as proposed herein, the reduction in color in passing through this reservoir being due to various causes, among which would be the fact that during the fall, winter and spring months when stream flow would be large, less color would be acquired by the water in passing through the marsh, and a portion of this water of low color would be held in storage in the reservoir and would mix with the more highly colored water coming down the stream in the summer months and tend to reduce the total color of the water drawn from the reservoir. Another important element acting to reduce the color would be the bleaching effect of sunlight acting upon the large surface of deep water in the reservoir. Distilled water has no color; waters having a color of from 15 to 20 on the platinum cobalt scale would begin to be noticeably discolored in a porcelain bath tub or wash bowl; when the color is above 30 it will be noticeable in a glass tumbler, and when above 50 it will appear to have a brownish cast. Very weak tea has a color of about 75. Swamp waters ordinarily have a color of 100 or more, some samples showing colors up even as high as 700 or 800.

It is questionable whether the water of the Lamington River at the site selected for the proposed reservoir ever has a color much in excess of 20 parts per million; the sample of which the

analysis is given in Appendix C represents the condition of the water at a very low stage of flow, there having been no rains on the watershed for several weeks previously, and the season having been an unusually dry one. The waters in several of the ponds from which Brooklyn's water supply is drawn frequently have colors as high as from 40 to 50 parts per million. The waters in the reservoirs of New York City have colors in some instances running as high as 40 to 50 parts per million, the average color of the water in the city street mains being about 20. The hardness of the New York City water averages from 30 to 40 parts per million after delivery to the city, the streams supplying the reservoirs in the Croton watershed having a hardness varying from 15 to about 70 parts per million. The hardness of the Black River water, 50 parts per million, represents not the average condition of the river, but the condition when the stream flow is least; after the water has been modified by storage and by the mixing of the storm waters collected during the fall, winter and spring with the water passing into the reservoir during the summer the effect will be to provide a water throughout the year having a hardness averaging less than the figure obtained in the analyses on September 16th. Taking all things together, it is my judgment that the water that will be derived from the Black River from the reservoirs proposed would have about the same general chemical and physical characteristics as the water supply of New York City.

The only respect in which Black River water, as drawn from the proposed reservoirs without filtration, might not entirely satisfy the inhabitants of Plainfield would be in regard to turbidity or muddiness. Plainfield has been supplied for many years with a clear colorless water derived from underground sources, and a very high standard has thus been unconsciously established with which comparisons would be made by the water consumers in the event of a new supply being provided. Unquestionably any natural surface water supply will be less attractive in appearance, and possibly less palatable, than the ground water now supplied to Plainfield. Surface waters almost always are slightly discolored, are usually very slightly turbid, and in the fall of the year sometimes acquire noticeable odors and tastes, due to plant life. These odors and tastes most frequently result from the secretion of pungent vegetal oils from cells of very small plants and organic forms, frequently microscopic in size, which grow in the water under favorable conditions of temperature and sunlight. In most instances these more or less unpleasant features are not sufficiently noticeable to cause complaint by the consumers. In other cases they are the cause of much dissatisfaction. When the storage in well proportioned reservoirs is

not carried beyond the point necessary to yield from 300,000 to 400,000 gallons of water per square mile of watershed per day troubles from odors and taste very rarely occur; on the other hand occasional objectionable turbidities will be experienced in such waters for the reason that the storage provided does not offer a sufficient length of time for the complete precipitation of all the mud brought into the reservoir by the stream. These periods of muddiness also are usually limited to perhaps once or twice during the year from a period of a week or two, and the muddiness during this time would not be high enough to cause unfavorable comment to persons accustomed to surface water supplies, the water having a slightly milky rather than a muddy appearance.

As to the pollution of the water from surface drainage and its direct contamination by the drainage of towns, farm buildings, etc., the conditions are those usually found in the establishment of gravity water supplies in this section of the country. Complete protection can be had from accidental pollution, such as the washing of infected matters into the reservoirs by rains and melting snow, etc., by the treatment of the water with a minute quantity of bleaching powder, as is practiced at the Boonton reservoir of the East Jersey Water Company.

In order to provide for rendering the water of the Lamington River perfectly safe as a municipal water supply, and acceptable in every respect as to color and turbidity I have provided in the estimates of cost for the installation and operation of a hypochlorite of lime plant, and for the installation and operation of a filter plant capable of removing all the turbidity from the river water so that it could be placed, in regard to appearance and quality on exactly the same basis as the very best ground water supplies.

Conduit Line to Plainfield.—It is proposed to build a gate house in the dam at the Hacklebarney reservoir, and to convey the water thence to a distributing reservoir back of Washingtonville, near Plainfield, through a pipe line following the least expensive route between the two points. It is proposed to build this pipe line of cast iron, riveted steel, or wood stave construction, according as local conditions of pressure and expediency indicate in each locality.

Two routes are feasible for the pipe line between the reservoir and the city, one being nearly straight, regardless of the heights of the intervening hills or depths of the valleys, the other following around the western slope of the Watchung Mountains so as to keep the pressures on the pipes lighter and hence permit the construction of a lighter and less expensive line. It happens that the higher level line is enough longer to counter-

balance the greater cost per foot of the shorter line and neither line, so far as cost is concerned, presents a material advantage over the other.

It is planned to build a 24-inch pipe line, with a slope, or head sufficient to deliver the water from the Hacklebarney reservoir over the summit of the Second Watchung Mountains, whence, after crossing the ridge the line will follow down the valley of Stony Brook to the distributing reservoir at Washingtonville. At some places the pipes would be under pressures due to heads of water up to about 400 feet. For these high heads riveted steel or cast iron pipes are proposed. Wood stave pipes of this size cannot be economically built for greater heads than about 200 feet under existing conditions, hence for heads greater than 200 feet steel or cast iron has been provided for.

After leaving the gate house at the dam the pipe line will follow down the river valley for a little over a mile, and then will swing around the face of the hill and take nearly a straight course to the gap back of Plainfield. Where it crosses streams and water courses it has been planned to use cast iron pipe which would also be used at all other places where erosion or other damage would be likely to occur.

Stand-pipes are provided for at intervals along the line, arranged with their tops at such a height that overflow will take place at each in case the pressures should be increased by the closing of valves in the pipe line. This is a safeguard to automatically keep the pressures within safe limits. Air valves to admit air at hill tops are also provided for in abundance as a measure to prevent the collapse of the pipe line under the influence of a partial vacuum which might tend to form in the line if a break should occur at the bottom of a valley and let the water out of the pipe rapidly. Air relief valves are also placed at summits to let the air out of the pipe when filling the line, and at the same time prevent the water from escaping. Finally gate valves are provided at intervals of about 2 miles in the main pipe line, blow-offs are provided at all valleys for emptying the pipe, and pressure relief valves are provided on portions of the pipe line where stand pipes would be impracticable on account of their height. The relief valves are to be adjusted to open automatically and permit the water to escape when the pressure exceeds the figure for which the valves are set.

No special difficulties are to be expected either in the construction of the dam or the pipe line, as both would be of well known, tried and satisfactory types.

Purification Works.—At the Plainfield end the pipe line would terminate at a basin holding about 300,000 gallons serving as a coagulating basin for the filter plant. The filters would

be of the rapid or mechanical type, of special design to remove the turbidity with the use of a minimum amount of coagulant, and arrangements would be made at the plant for the use of bleaching powder, particularly at times of flood flows in the Lamington River. These filters would be of inexpensive, though permanent construction, simple and easy to operate, and the motive power for compressing the air for washing purposes and for pumping filtered water for washing the filters would be derived from a water-wheel operated by the unfiltered water under the head available between the filter plant and the top of Second Watchung Mountain where the pipe line crosses the ridge.

Distribution Reservoir.—The filtered water would be discharged into a covered filtered water reservoir of concrete holding 4,000,000 gallons for the first installation, increased to 8,000,000 gallons when the water consumption shall have reached that figure.

There are several places where the filter plant and distributing reservoir could be conveniently located. The point shown on the plans, near Washingtonville, is one only of several good sites. The only requirements would be that the elevation of the site be such as to afford a water level in the reservoir of 300 feet above sea level, and that the site be suitable for construction purposes and that it be conveniently located.

Connecting Mains.—From the distributing reservoir the water would be conveyed to the street mains in Plainfield through a 24-inch main, dividing into a 16-inch and a 12-inch branch.

Interference With Water Powers.—Below the proposed reservoir several water powers will be affected by the diversion of the water of the river. These are described in Part II.

Cost of Construction and Operation.—The cost of constructing and operating this plant, complete, including the purchase of the existing or the laying of new street mains in Plainfield, would be as given in Table XV.

TABLE XV.

Capacity of plant. Gallons daily.	Cost of Construction.	Annual cost of operation.	Cost of water per 1,000 gallons.
4,000,000	$1,161,000.00	$80,000.00	5.5 cents.
8,000,000	1,374,000.00	94,000.00	3.2 cents.

The detailed costs of construction and operation will be found in Appendix E.

PART V.

Gravity Supply from the North Branch of the Raritan River at Ralston.

At Ralston the North branch of the Raritan River lies about 4½ miles east of the Black, or Lamington River, and flows in a general southerly direction.

Location.—At a point about a mile and three-quarters below Ralston there is a very good site for a masonry dam, solid rock being exposed in the bottom of the creek and on the hillside, each side of the narrow valley. Above this point the drainage area is estimated to be 16.70 square miles. About half a mile above the dam site the valley spreads out into an open basin affording large storage.

Topography and Geology.—Generally speaking, the watershed is mountainous, although quite extensively farmed and cultivated. The rocks are granitic and the water of the river consequently is soft. The conditions governing stream flow are, in the main, similar to those of the Lamington River, and no unusual phenomena as to extreme flood flows or extreme low water flows are to be expected. The absence of extensive marsh lands on the watershed favors a water low in color, but the more extensive pollution from the surface drainage shows in a somewhat higher number of bacteria per cubic centimeter of the water and in a slightly greater amount of free and albumenoid ammonia. The water contains enough iron in solution to cause trouble, however, if not treated in a way to secure its removal. This can be readily accomplished by the aeration and filtration of the water by mechanical filtration, which would be required, in any event, on account of occasional turbidity, the same as the Lamington River water.

Sources from Which Pollution May Come.—Ralston, a small village, lies at the upper end of the proposed reservoir and some danger would exist of the direct pollution of the water from this source. To guard against this, it would be desirable to establish a system for collection and removal of the wastes of the village, in which there are perhaps 12 or 15 houses, a mill and a general store. This could easily be done and with the filtration of the water, combined with the occasional use of hypochlorite of lime the water from this reservoir would conform to all the established standards. The analysis of the river water September 16th, 1910, is given in Appendix C.

Quality of the Water.—The effects of collecting this water in a large storage reservoir would be similar to those described in connection with the Lamington River water, tending to reduce the turbidity, color, hardness and other mineral constitu-

ents, as well as the organic pollution and bacterial contents. When delivered to the consumers, in Plainfield, this water, after treatment as proposed, will be soft, clear, colorless, sparkling and safe from a sanitary standpoint; equal in all respects as to appearance and safety to the present ground water supply, and very much softer.

Quantity of Water Available and Storage Required.—The site chosen for the dam is well suited for the purpose and will permit of building the dam to a height of about 80 feet so that the water surface can be backed up to an elevation 400 feet above sea level.

This reservoir would be at an elevation 200 feet lower than the one proposed on the Lamington River and for this reason necessitates following a different route with the pipe line and also requires a larger conduit by reason of the smaller available head or pressure.

The available storage capacity of the reservoir, I estimate, to be about 1,360,000,000 gallons, or about 80,000,000 gallons of storage per square mile of watershed. The water surface of the reservoir, when full would be about 2 per cent. of the area of the watershed, and from these data the estimated quantity of water that could be drawn from each square mile of watershed would be about 500,000 gallons daily, of 8,500,000 gallons daily from the entire watershed.

There would be required, for the reservoir and for protection of its waters the purchase of about 250 acres of land, a large part of it not of great value. It would also be necessary to purchase two water powers, one not of much value, but the other a developed and used power in fair condition. It would also be necessary to build about 3½ miles of new roads to replace those that would be obliterated by the flooding of the valley, and to relocate and rebuild about one mile of the Rockaway Valley Railroad.

Water Powers Interfered With.—Below the proposed reservoir the interests that would be affected by the diversion of the water would be the water powers and rights mentioned specifically in Part II.

Conduit Line to Plainfield.—Owing to the low elevation of the reservoir at Ralston and to the height of the lowest point in the crest of Second Watchung Mountain, it is impossible to take the conduit line to Plainfield in a direct line, the course having to be changed to avoid the high summit. This necessitates following the valley of the North branch of the Raritan down as far as Far Hills, then swinging around on the southerly face of Second Watchung Mountain, climbing up so as to enter the valley between the First and Second Mountains and following

this along the route approximately as shown on the map, to the site of the distribution reservoir at Washingtonville. The considerable length of this line, together with the limited fall or slope available, necessitates the use of a pipe line 30 inches in diameter. With the greater head available from the Hacklebarney reservoir a 24-inch pipe on a short route was sufficient.

The conduit line would, in essential matters, be similar to that described in Part IV. foı the Lamington River supply, being a composite line made up of 30-inch wood stave pipe, 30-inch cast-iron and 32-inch riveted steel pipe, with blow-offs, gate valves, stand pipes, air valves, air relief valves and pressure relief valves as required.

No special difficulties likely to increase the cost beyond the estimates are anticipated in the location or construction of the line and no unusual difficulties are expected in matters of rights-of-way. So many alternate routes are available for a pipe line of this sort that little difficulty need be feared in matters of right-of-way.

Purification Works.—At the Plainfield end of the conduit line the water would be delivered into a coagulating basin holding about 500,000 gallons from which it would flow to the filters and thence, after purification, to the 4,000,000 gallon covered distributing reservoir.

A purification plant similar to the one proposed for the Lamington River water would be provided for this installation, the only difference being that auxiliary power, furnished by gasoline engines would be required to supply wash water and compressed air for washing the filters. The use of hypochlorite of lime would be availed of in connection with this plant, as with the Lamington River plant. The statements regarding conveyance of the water to Plainfield, and the location for the reservoir and purification plant, given in connection with the description of the Lamington River supply apply equally to the supply from the North branch of the Raritan at Ralston.

Cost of Construction and Operation.—The estimated costs of constructing and operating these works complete, including the purchase of the existing, or the laying of new water mains in Plainfield, would be as given in Table XVI.

TABLE XVI.

Capacity of plant. Gallons daily.	Cost of Construction.	Annual Cost of operation.	Cost of water per 1,000 gallons.
4,000,000	$1,325,000.00	$91,000.00	6.2 cents.
8,000,000	1,531,000.00	106,000.00	3.6 cents.

The detailed estimate of cost of construction and operation will be found in Appendix E.

PART VI.

Gravity Supply from Green Brook and Stony Brook.

Many years ago it would have been feasible to secure a gravity supply of water from Green and Stony Brooks of a quality and quantity sufficient to warrant its development; today this is not feasible nor desirable.

Green Brook alone with a watershed of 7.8 square miles could probably be developed to yield a total of about 5,000,000 gallons daily, and about 3,000,000 gallons daily could be had from Stony Brook. All the water that either one of these watersheds could yield, would, therefore, be required for the present needs of Plainfield. The water from either of the watersheds would require very careful purification, and sterilization, and in neither case could it be collected at a high enough elevation to give satisfactory pressure in some parts of the town.

A careful inspection of the watersheds of these streams convinced me of the undesirability of planning for their development for water supply purposes. Both valleys contain a large population relatively to the stream flow, and in both are indications of a probable, continued increase. The cost of the development of a supply from Stony Brook would be rendered excessively high by the high cost of land for reservoir purposes and the compensation that would have to be awarded to riparian owners for the diversion of the water, extinction of business investments and acquisition of valuable properties.

Preliminary estimates indicate that, on account of the great amount of storage required, more than 1,500,000,000 gallons, to enable these two streams to yield the required 8,000,000 gallons of water daily, with the necessary high dams on somewhat uncertain foundations as to water-tightness, the cost would exceed the cost of going over 19 miles away to get the water of the Lamington River or the North branch of the Raritan, the water from both of which streams would be better in quality than that collected locally, could be delivered at a higher elevation at Plainfield, and could be developed, when necessary, to yield more than the 8,000,000 gallons daily, which would not be possible in the case of Stony and Green Brooks.

In my judgment these streams cannot be considered of value as sources of water supply for Plainfield.

PART VII.

Pumped Supply from the North Branch of the Raritan River at North Branch Station.

Location and Quantity of Water Available.—The Raritan River at North Branch Station of the Central Railroad of New Jersey has a watershed of 189.4 square miles from which, judging by the gaugings recorded at Raritan as well as of the flows of other streams, the low water flow would be about 27 cubic feet per second, or 17,300,000 gallons per day. It would be feasible, therefore, to secure a supply of water for Plainfield from this stream.

Natural Quality.—The water, in its natural condition, of course, would not be suitable for use. It would be, at times, very muddy, and much polluted in various ways. A reference to the analysis of the water in Appendix C shows it to be somewhat colored, somewhat high in nitrogen, and iron and to carry fairly high numbers of bacteria. It is, however, a water that can, by proper treatment, be rendered acceptable in every respect.

Treatment Required.—With subsidence, filtration and treatment with hypochlorite of lime when needed, it can be rendered clear, colorless, odorless, sparkling and safe from a sanitary point of view; in fact, superior, because of its softness, to the water now supplied to Plainfield from the Netherwood plant.

Supply Works.—The plan proposed for securing water from this point is to purchase about 20 acres of land fronting on the river in a location to which a side-track could be conveniently laid from the Central Railroad of New Jersey and build thereon a pumping station and purification plant.

Purification Plant.—Water would be taken out of the river through a concrete intake channel of large cross-sectional area, provided with screens to arrest floating matter and ice, leading to a pump well from which steam driven centrifugal pumps would lift it to a concrete-lined open sedimentation basin holding 1,500,000 gallons. Arrangements would be made to add the coagulant to the water as it enters this basin, and also as it leaves it, when desired. From the basin the water would flow by gravity to the filters, which would be of the rapid or mechanical type and after filtration would pass to a small covered clear water pump well holding about 300,000 gallons.

Pumping Machinery.—Economical steam driven crank and fly wheel pumping engines would take the filtered water from this pump well and force it through a 28-inch riveted steel force main to a 4,000,000 gallon covered distribution reservoir at Washingtonville, from which it would pass to Plainfield and

be distributed in new street mains or in the existing mains in case these should be purchased from the Plainfield-Union Water Company, or be acquired by condemnation.

Building.—At the pumping station the work would all be of reinforced concrete, the superstructures being brick with slate roof and all of a substantial permanent nature and architecturally pleasing. The machinery provided for is first-class in every respect and suited for economically performing its duty.

The filters would be of concrete construction of modern design, fully equipped with all the best devices for control and registration and the best and most reliable machinery for handling and controlling the use of the coagulant and lime solutions, as well as the hypochlorite of lime when needed.

Capacities.—The capacities of all parts of the plant would conform to the requirements stated in Part II so that it would be able to respond to all demands.

Force Main to Plainfield.—The conduit line proposed would be a riveted steel pipe line of ample thickness, coated with the best and most durable protective coating for this kind of pipe and would be laid below frost-line.

Its course would be easterly, from the pumping station to the gap through which Middle Brook issues from the valley between First and Second Watchung Mountains, passing through the gap and following the valley eastward to the reservoir back of Washingtonville.

Distributing Reservoir.—In this case the filter plant, as noted, is located at the source of supply instead of at the Washingtonville reservoir as was the case with the supplies from Ralston and Hacklebarney reservoirs. The general alignment for the conduit line and the locations of the pumping station, filter plant and distribution reservoir are shown on the map.

The conduit line will be provided with air valves, air relief valves, gate valves, blow-offs and pressure relief valves, where necessary to secure proper operation and permit of inspection and re-painting inside, at intervals as deemed necessary.

No special difficulties are anticipated in the construction or operation of these works or in the securing of the necessary rights-of-way or privileges.

The first installation provided for in the estimates would have sufficient pumping and filtration capacity to handle 4,000,000 gallons daily, a force main to Plainfield with a capacity of 8,000,000 gallons daily, and a 4,000,000 gallon covered reservoir at Washingtonville. For the second estimates, providing for a daily consumption of 8,000,000 gallons the pumping station equipment, filter plant and reservoir at Wash-

ingtonville would be increased in size, but the force main provided for in the first estimate would be of sufficient size.

Interference With Water Powers.—Below the proposed works several water powers would be somewhat affected by the diversion of the water. These are described in Part II.

Costs of Construction and Operation.—The estimated cost of constructing and operating these works complete, including the laying of new or the purchase of the existing water mains in Plainfield, would be as given in Table XVII.

TABLE XVII.

Capacity of Plant. Gallons daily.	Cost of Construction.	Annual Cost of operation.	Cost of water per 1,000 gallons.
4,000,000	$1,009,000.00	$93,000.00	6.4 cents.
8,000,000	1,177,000.00	134,000.00	4.6 cents.

The detailed estimates of cost and construction and operation are given in Appendix E.

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PART VIII.

Pumped Supply from Passaic River at Berkeley Heights.

Watershed Area.—The Passaic River above Berkeley Heights has a total watershed of about 90.0 square miles, approximately one-third of this area being the level bottom lands and marshes in the bed of the glacial Lake Passaic and the other two-thirds the highlands, those on the north being in the granite hills and on the south in the shale and trap formations of the Watchung Mountains. The flat areas are very extensive, and while only portions are true swamps all the year round, a large proportion is subject to submergence during the spring and winter months. The existence of this swamp area has much to do with the appearance and quality of the water, the effect being, in most particulars, the reverse of beneficial.

Quantity of Water Available.—The topographical, geological and meteorological conditions on this watershed are favorable to a fairly well sustained summer flow in the river, as is shown by a gauging at Chatham, where, with 100 square miles of watershed, the lowest measured flow is 9,000,000 gallons daily.

Quality of the Water.—While there are no large cities on the watershed above Berkeley Heights, the population on the watershed is large and the river receives a large amount of farm and surface drainage as well as washings from the streets of many small towns and settlements, and some drainage from buildings and mills.

Reference to the analysis of the water, given in Appendix C, shows considerable turbidity, high color, noticeable odor, considerable organic matter in solution, a high iron content, high chlorine, high numbers of bacteria, many forms of microscopic plants and much evidence of the decomposition of organic matter. The water in its natural condition would not be fit to use. By proper treatment it can be rendered clear, odorless, not too highly colored to be entirely acceptable, and safe from a sanitary point of view. Its relative softness is much in its favor. Nothing could be done to prevent the pollution referred to, so that corrective treatment of the water itself would be essential. Fortunately means are available for removing all the objectionable features and rendering the water after treatment capable of conforming to the established standards.

No storage can be secured at this point, or at any higher point where a supply sufficient for Plainfield's needs could be taken, without flooding such an enormous area that the cost of the flooded lands would be beyond the reach of Plainfield. For this reason the quantity of water that could be secured would be limited to the natural flow of the stream.

Location of Works.—The plan proposed contemplates building a pumping station and filter plant at Berkeley Heights and pumping the filtered water over the mountain to the Washingtonville reservoir, from which it would be delivered to Plainfield through pipes connecting with the street mains in Plainfield.

In general, the arrangement and capacities of the pumping equipment and filter plant would be similar in all respects to those for the North Branch plant, except in the matter of the high lift pumps which, in this case, would be smaller in power, as the total lift would be less.

The cost of operation of the filter plant for this water would be higher than for the North Branch plant as more alum would be required, on account of the high color, the suspended matter and organic matter in the water, and also soda ash or lime would have to be added to the water a large part of the time on account of the low alkalinity when the marshes are submerged during floods.

Intake and Sedimentation Basin.—The water would be taken from the intake by low lift centrifugal steam-driven pumps and delivered to the sedimentation basin holding 1,500,000 gallons, and thence, after filtering and treating with hypochlorite of lime, be pumped with high duty pumping engines through a 28-inch steel force main to a small covered tank on top of Second Watchung Mountain. From this a pipe line will lead down the valley to the Washingtonville covered reservoir, and thence to Plainfield as in all the plans hereinbefore described.

Force Main.—The pumping station and filter plant would be located on a 20-acre tract of ground bordering on the river in the neighborhood of the crossing of the Passaic and Delaware branch of the Delaware, Lackawanna & Western Railroad. The force main would lead, in as straight a line as practicable, from the pumping station to the lowest point in the crest of Second Watchung Mountain, as shown on the map, where it would end in a small concrete tank, provided with an overflow, as previously mentioned. The pipe line would be riveted steel, properly coated, and provided with the necessary gate valves, air valves and relief valves, manholes, and pressure relief valves.

Purification Plant.—The type of filter plant, pumping station, distributing reservoirs, connecting pipes and street mains would be similar to those described for the North Branch plant; and side tracks to the railroad, together with all necessary appurtenances of every description, are included in the estimates of the cost of constructing the works.

No unusual difficulties would be encountered in the construction of the works, but the diversion of the water would

require payment to riparian owners below of sums to compensate for the damage done; this subject has been discussed in Part II. An allowance for interference with these rights has been included in the estimates of cost of construction.

Costs of Construction and Operation.—The estimated costs of construction, and annual cost of operation would be as given in Table XVIII.

TABLE XVIII.

Capacity of Plant. Gallons daily.	Cost of Construction.	Annual Cost of operation.	Cost of water per 1,000 gallons.
4,000,000	$805,000.00	$81,000.00	5.5 cents.
8,000,000	973,000.00	116,000.00	4.0 cents.

The costs of construction include the cost of all works for procuring the new supply and delivering it to the consumers in new water mains to be laid in the streets in Plainfield, or in the present mains, if acquired by the city.

The costs of operation include all operation costs, and all administration and maintenance charges.

The detailed estimates of cost will be found in Appendix E.

PART IX.

Pumped Ground Water Supply.

Geological.—The shale rock underlying the Atlantic coastal plain in the district immediately north and east of the Raritan River is more or less seamed, folded and shattered as a result of the movement of the earth's crust in past geological ages. There is so much literature available regarding the geological structure of this portion of New Jersey, particularly in the annual reports of the State Geologist, that it would seem unnecessary to repeat here an extended description of the different formations and their histories. The bed rock underneath Plainfield and the immediate vicinity for a considerable depth is of sedimentary origin, being composed of shales and sand stones of comparatively recent formation. In some portions beds of limestone are interspersed between the shale, and immediately back of Plainfield two deep beds of trap rock are exposed along the faces of First and Second Watchung Mountains, these trap beds being separated by beds of shale several hundred feet in thickness. Geologists describe these trap beds as having been formed by an outflow of lava upon the surface of the sedimentary rock, to be followed later by the deposition of the shales lying upon the lower trap bed, after which a succeeding eruption caused the overflow of the large area of trap rock in the upper bed; still later were deposited upon this trap rock, other beds of shale and sand-stone.

There are reasons to believe that this was the case rather than that the trap beds were formed by the forcing of molten lava between the beds of shale. Whatever may have been the origin of this complicated structure it is certain that subsequent to the formation of the trap beds there was a great movement in the earth's surface by which the strata were disturbed from their normal positions resulting in the formation of faults and crevices, and splitting the beds on their seams horizontally as well as vertically. Adjacent portions of the rock beds were ground together during this movement, and over large areas the rocks were shattered and crumbled and in some places the seams were opened between the strata. This shattered condition, of course, does not cover or extend over the entire area, but would be apt to follow along the line of faults and fissures. Owing to this shattered condition of the rock, and also to the porosity of the sand-stone beds interspersed through the shales, ground water percolates down and fills the pores and open spaces in the rock. It is hardly possible to sink a well into the underlying rock anywhere in this general vicinity without striking water. Some

of the wells yield large supplies, others yield barely enough for the supply for a single household.

Location of Wells.—On the map are shown the locations of several wells and water supply plants securing underground water in the general vicinity of Plainfield. Wells which furnish water from the shale and sand-stone rocks are shown with a circle containing a cross; wells which derive their supplies from the gravels and sands overlying the rock are shown by a solid circle. By far the greater number of wells, it will be seen, are supplied from the debris-filled faults, open seams between the folds, and other porous portions of the rock beds. In Appendix B will be found a list and description of 242 wells in this vicinity, the data for which have been supplied by the drillers of the wells. A careful study of these records has been made in connection with the geological conditions of this district, a brief description of which is given in Part III, but certain features not mentioned therein are of special interest in this connection.

Configuration of Rock Surface.—From the records of the wells described in Appendix B and from cross sections through Plainfield, on several different lines, furnished by Mr. Andrew J. Gavett from a compilation made from various sources by him in 1894, it has been possible to ascertain approximately the configuration of the surface of the underlying rock over an extensive territory to the east and north of the Raritan River between New Brunswick and the Atlantic Coast. A portion of this territory only is shown on the map, that which lies east of Roselle having no special significance here. It will be seen that the surface of the rock, which is shown on the map by dotted contours, is very irregular in elevation varying from over 60 feet below sea level at a point between Springfield and New Orange to about 100 feet above sea level back of Scotch Plains, and also a few miles south of South Plainfield. It will be seen, also, that there are two well-defined valleys in this rock formation, one filled with glacial deposits, and very deep and narrow, extending from the neighborhood of Short Hills and running southeasterly towards Newark Bay, and the other, less sharply defined, starting from the same general locality and swinging southerly towards Perth Amboy. Other small valleys also appear, notably one which passes southwesterly under Westfield and Plainfield towards the Raritan River at Bound Brook. In this latter valley the rock is, in some places, very deep below the surface, being probably about 100 feet or more under Dunellen. These valleys at the present time, have very little influence on the direction of the flow of ground water, although in ancient times undoubtedly the deeper valley run-

ning eastwardly from Short Hills was the outlet for the drainage of the Passaic River basin. An interesting description of this and of the glacial lake, Passaic, will be found in the annual reports of the State Geologist of New Jersey and in the United States Geological Survey report on this district.

Surface Formations.—Overlying the rock surface above described are various deposits, some of which are of glacial origin, and others are formed by the decomposition of the rocks themselves. A large amount of material was washed into the outlet of the Passaic at Short Hills during glacial times, the enormous deposits of gravel, clay and sand at Short Hills and Summit being of this origin. The great glacier covered practically all of the territory east of the land where Plainfield now stands, the western edge of the terminal moraine being easily traceable from Staten Island to Plainfield, and then north to Summit, Chatham and Madison, passing east of Morristown and northerly to the west of Boonton and thence running nearly west for many miles. These deposits in some places are unchanged and vary in depth as well as in the nature and appearance of their surface topography. To the east of Plainfield the deposits were left in mounds or low hills between some of which are partly defined valleys and between others depressions containing marshes and small ponds. Wherever the water from the melting glacier broke over the edges of the moraine the sand, gravel and clay were washed down into the valleys on the lower plains and there settled out of the water according to their different subsiding values, the clays being carried farthest away, when there was a free outlet for the water, or being deposited in strata on top of the gravels and sands wherever the outlet was dammed up so as to form a pond or basin. In the Plainfield basin the evidences are strong that both of these conditions existed at different times for the glacial materials are found stratified in an irregular way, some of the strata being water-bearing and others not.

The plain on which Plainfield rests is largely of glacial origin, but is covered, particularly on the western side, with the debris resulting from the destruction of surface outcrops subsequent to the time of the formation of the glacial deposits. Apparently the materials in the moraine to the east of Plainfield have not been significantly disturbed since their deposition. They vary from a few feet to over a hundred feet in depth and in nearly every case wells sunk therein have failed to yield water in quantities worthy of consideration. In the plains surrounding Plainfield, however, and in the plains overlying the deep valley of the ancient Passaic in the neighborhood of Union, Springfield and Milburn and Short Hills, the gravels and sands in every case, yield water in large quantities. In general in Piscat-

away and Raritan Townships, outside of the Plainfield plain, there is very little soil on top of the rock excepting that which has been produced by the disintegration of the red shale rocks. In the valley of Cedar Brook practically all of the soil has been washed into the valley either during or subsequent to the glacial period and the soil is here of great depth.

The tightness of the materials forming the terminal moraine to the east of Plainfield practically cuts off accession of ground water to the previous gravels in the Plainfield district from any surface territory excepting that which is immediately tributary to the valley of Green Brook.

Sources of Water and Yields of Wells.—From the above brief description of the geological and topographic features of this district it will be observed that the water can be secured from the ground from two different sources, one being the gravels and sands resulting from the out-wash of the glacial deposits, and the other being from the pores and fractures in the underlying bed rock. The porous sands and gravel can generally be availed of to the extent of from 1,000,000 to 5,000,000 gallons per day of water at a well designed plant, the amount depending upon the depth of the strata, the depth to which the water can be drawn down in the wells and the area from which the water can be secured. Similarly wherever favorable places can be found for the establishment of a well plant taking water from the underlying rock large quantities of water can likewise be secured, although it is much more difficult to locate a satisfactory source from the rock strata than from the gravels. It is rarely that a single well driven into the underlying rock has yielded more than 500,000 gallons of water per day, yet several now in operation drawing water from this same formation in other localities are yielding this quantity. Usually along this portion of the Atlantic coastal plain the sand-stones and shales seem to yield most water at elevations considerably below sea level. For instance, in the first 25 wells in the list given in Appendix B all of those which penetrated into the rock secure the water at elevations of from 10 feet to about 150 feet below sea level. Four of the wells, namely, 14, 15, 17 and 18 did not penetrate the rock excepting for a foot or two, and have a very small yield, the water being secured on top of the shale rock.

But nearly all of the wells given in the list were driven for private parties wishing small supplies of water and the quantities yielded under test, as reported, do not represent the quantities of water that could be secured, but, rather, the quantities that were secured in sufficient amount to satisfy the desires of the owners. Few of the wells in the list were drilled to great enough depths to expect a large yield of water, most of them being only

a few feet deep below the elevation where the water was struck.

An examination of the records of wells 12, 13, 14, 15, 16, 17 and 18, in the western edge of the terminal moraine shows that in no case was water struck until the surface of the rock was reached. Number 17 was originally a dug well 80 feet deep, which failed and was deepened by driving a 6-inch well through the bottom to rock, where water was struck. This group of wells illustrates the tightness of the original deposits of the terminal moraine. The wells varied from 100 feet to 234 feet in depth, and were all 6 inches in diameter.

Supply for Plainfield.—From a consideration of the records of the wells listed in Appendix B and of others in similar formations elsewhere and from a careful consideration of the character of the geological formations it is my judgment that a sufficient quantity of water could be had from the shale and sandstone formations in the neighborhood of Plainfield for the supply of that city independently of the works of the Plainfield-Union Water Company. The effect of pumping at the Netherwood pumping station on ground water levels in that vicinity did not extend, during the past summer, more than a mile to the south. This is indicated by the fact that the ground water levels in the valley of Cedar Brook near which the sewage pumping station was being constructed were not lowered by the pumping at Netherwood. Other considerations also lead to the general conclusion that this would be the case, so that there is still available from the gravel deposits in the vicinity of Plainfield a very large supply of ground water if properly collected.

The quantity of water that could be obtained from any one well driven into the rock formations can not be told until the well has been driven and tested and no positive statements can be made at this time as to the result of putting down a well at any particular place. If it should be decided later to adopt a supply from this underground source, it would be essential, before committing the city to a definite location, to sink a number of test wells so as to make a thorough survey of the underground waters in the vicinity which judgment would indicate to be most likely to yield water in satisfactory quantities.

I believe that 12-inch wells driven down sufficiently deep into the rock and equipped with proper pumping machinery could be depended upon to yield up to 500,000 gallons daily each providing these were located where they did not interfere with each other in abstracting the water from the rocks. Inasmuch as apparently the water to be secured from the rock strata in that neighborhood lies at considerable depths below sea level there could be little question as to the continuance of the supply in case a satisfactory yield were secured at the start. All the

ground water must find its outlet into the sea unless its motion has completely stopped, and hence, this water being found at an elevation lower than sea level would be drawn through the crevices of the rock from a very large territory, or superficial watershed. The source of this water is, of course, unknown. On top of the shales and sand-stones there apparently is a bed of nearly impervious material as in few cases is the water struck until the wells have penetrated some distance into the rock. It is true that in some instances test wells driven into the shale rock have failed to produce water, notably one which was driven to a depth of 500 feet for the Riker Motor Company, at Elizabethport; another well driven for this same company a short distance from the dry well yielded 100,000 gallons per day at a depth of 150 feet. Among the wells in the list are several which yield over one-half million gallons of water per day, and some over a million gallons per day per well from the shale rock.

As to how many wells should actually be driven to secure a supply of 8,000,000 gallons per day for Plainfield from the shale rock, that can only be told after test wells have been put down. It is my judgment that using 12-inch wells and driving them to a depth of about 400 feet and making arrangements to pull the water level down in the wells at least 100 feet with pumps, it would be safe to figure on securing one-half million gallons per day per well, up to a total of the required 8,000,000 gallons, the wells being not nearer together than 1000 to 1500 feet, so as to cover sufficient territory to assure that the wells shall not rob each other of water. This provision is, of course, an estimate and as such is subject to modification in the event of more accurate disclosures by test wells, but it is, in my judgment, sufficiently conservative to permit of making an estimate of cost of securing a supply of water from this source, and it is upon such conditions that the estimate following hereafter is based.

Quality of the Water.—The quality of the water derivable from the shale rock is good in all respects, barring hardness. In this respect waters from different localities and different strata vary greatly.

An examination of the analyses of the water from the Spicer Manufacturing Company's well (No. 42) in Plainfield, this same company's well in South Plainfield (No. 42 A) and The Aeolian Company's well in Cranford (No. 58) show this variability as to hardness. The bracketed numbers refer to the descriptions of the wells in Appendix B, and indicate also their locations on the map.

The water from the Spicer Manufacturing Company's well in Plainfield, (No. 42) is soft enough for use for all ordinary pur-

poses without treatment, being in fact not significantly harder that the water of the highland surface streams in that portion of New Jersey. (See analyses of Lamington, Raritan, Passaic and Rahway Rivers, and Normahiggan Brook waters in Appendix B.) The waters from the other wells, as well as from the Plainfield-Union Water Company's supply, are hard enough to warrant softening. No trouble is likely to be experienced with iron in any of these waters, the ground waters being relatively free from it and also low in free carbonic acid gas.

No exception can be taken to any of the waters from deep wells in Plainfield or its vicinity, where properly driven and cased, from a sanitary point of view. They all show water of great purity excepting for their mineral constituents and these are not in any way injurious to health. Apparently all surface waters which reach these rock crevices have been filtered and purified, and are completely protected from direct contamination by the overlying deep beds of gravel and sand, and by impervious strata. They are clear, colorless, odorless, healthful and agreeable in taste and temperature, are not too hard to be successfully softened nor are they hard enough to make the cost of softening excessive. In other words, by a simple process, and at reasonable cost, they can be treated so as to render all of about the same quality, as to hardness, as the waters from the mountain streams in the highlands.

Development of Supply for Plainfield.—Two plans have been considered for developing a new ground water supply, one on the assumption that water as soft as that yielded by the Spicer Manufacturing Company's Plainfield well can be found and the other that the water, when found, will be as hard as that from the Aeolian Company's well, and will require softening.

Wells and Pumping Plants.—The first of these plans contemplates the sinking of sixteen 12-inch wells to an average depth of about 400 feet, the wells to be from 1000 to 1500 feet apart, located in accordance with the indications of test wells to be sunk for the purpose. Each well is to be cased for sufficient depth to cut off all surface water, and to have a small masonry house over it containing a deep well pump head driven by a direct connected electric motor and controllable from a central power station. From each pump a pipe connection would be made to a force main leading to a connection with the street mains in Plainfield, so that each pump would take the water from its well and deliver it directly into the street mains without a second pumping.

Central Power House.—The power to operate the small pumps would be derived from a central power house, to be built for the purpose, containing a producer gas plant and gas engines

direct connected to the dynamos. The house would be equipped with such number of units, both as to gas production, power and electrical energy as would give flexibility in operation and provide spare units at times of maximum output. Power would be conveyed to the small pumping units in cables leading in underground conduits from the switch board of the main station. Track facilities would be provided for rail connection for the delivery of coal and supplies and a modern system of coal handling machinery would be installed. There would also be in connection with this plant, a distributing reservoir, as in the other plans heretofore described, and a system of pipes for connecting the reservoir with the street mains in Plainfield.

Estimates of Cost of Construction and Operation.—The estimates of cost of construction include an allowance of $50,000.00 for the purchase of land for the establishment of a plant of this character. It is not essential that a tract be purchased large enough to include all the wells, as, if found necessary these could be located on small isolated tracts with rights-of-way for the pipe lines and electric conduits. The estimates of cost cover the best and most reliable types of machinery that can be purchased for the respective parts of the plant, and the buildings and all appurtenances are to be of permanent and suitable construction.

A summary of the estimated costs of construction and annual cost of operation and maintenance of the plant, for yields of 4,000,000 gallons and 8,000,000 gallons per day is as given in Table XIX.

TABLE XIX.

Capacity of Plant. Gallons daily.	Cost of Construction.	Annual Cost of operation.	Cost of water per 1,000 gallons.
4,000,000	$714,000.00	$67,000.00	4.5 cents.
8,000,000	962,000.00	100,000.00	3.4 cents.

Alternative Plan.

In case the water secured from the deep wells should not be sufficiently soft a change in the plan outlined above would be necessary. As before, the individual wells would be supplied with motor-driven pumps, but the water instead of being delivered into the street mains direct would be pumped through a force main leading through the streets of the city to a softening plant located at the Washingtonville reservoir where, after softening it would pass to the distributing reservoir and thence to the street mains in Plainfield as in all the other plans.

In all other essential particulars this plan would be identical with the works just described for an unsoftened ground water supply.

Costs of Construction and Operation.—A summary of the cost of constructing and operating the plant for the two stated capacities would be as given in Table XX.

TABLE XX.

Capacity of Plant. Gallons daily.	Cost of Construction.	Annual Cost of operation.	Cost of water per 1,000 gallons.
4,000,000	$ 841,000.00	$87,000.00	5.9 cents.
8,000,000	1,113,000.00	133,000.00	4.5 cents.

This plan, while naturally more expensive to build and operate than the plant for the unsoftened supply, would still be more economical than to try to purchase the Netherwood plant of the Plainfield-Union Water Company, provide for the softening of the water and extend the works, later, to a capacity of 8,000,000 gallons daily. The only way that this can be shown is by making an approximate estimate of the cost of such improvements and comparing the results with the estimates just presented.

Improvement of Netherwood Supply.

Naturally an estimate of cost, as above outlined, to be complete, should include the value of the wells and pumping machinery, and of the ground the plant occupies, as well as an allowance to cover the franchise rights and the damage that would be done to the company by taking away its source of supply from which it also supplies other municipalities under contractual relations. It should also include the proportionate part of the cost of the large connecting mains the company has laid between the different municipalities, and various other items of cost and expense that go to make up the going business of which the company would be deprived if its source of supply were taken away. There is no way, at the present time, by which a value could be put on these items unless the company were a willing seller and would by agreement accept a sum mutually agreeable to the city and the company. This, I am given to understand, cannot be brought about, and to one not acquainted with the details of the company's business it would be impossible to fix on a valuation that would be just to both parties. I shall not attempt to set a valuation, therefore, on the company's intangible property and will merely point out that this valuation would be large, particu-

larly if the acquisition of the property extinguished the company's rights to secure water at this point through the establishment of another plant.

Value of Netherwood Plant.—The value of the physical property of the company in Plainfield, outside of the street mains and appurtenances would hardly be represented by the actual cash outlays that have been made in bringing the plant to its present condition, as several changes have been made which could have been avoided with reasonable foresight when the plant was much smaller than now; also in some respects, the plant has deteriorated in value. On the other hand the company owns property in Plainfield which has materially increased in value since the plant was built. The value of the wells and pumping station in Plainfield and the land upon which they stand is small as compared with the cash value of the company's franchise rights and the proportionate part of the connecting mains to the east. This should be kept clearly in mind in considering the following statements regarding the adaptation of the present water works plant to conform to the same standards as to the quantity and quality of the water as have been considered in the proposed new plants. For the comparison I have in mind it is not essential that the assumed valuation of the physical plant should be exact.

As has already been described, the water from the Netherwood plant is harder than our established standards, and to bring it within these limits would require that it be softened. Also, it has been shown that the capacity of the plant, that is, its capacity to yield water continuously without danger of having the draft exceed the supply to the wells through a long series of years, would be not over 3,000,000 gallons daily, but under favorable conditions of rainfall distribution might reach 4,000,000 gallons daily, which is the amount that should be provided for in the first installation of a new plant. In order to place the plant on a parity with the others heretofore described, therefore, extensions should be made in the future so as to double the supply at present available. The Plainfield-Union Water Company is now carrying out improvements in this direction at the Netherwood plant and its efforts to secure a large additional supply may prove successful, although this would be more certainly assured if the wells were further apart than they are being driven. My judgment of the distance to allow, for purposes of estimate, is stated above and in order to place the plant upon the same basis for comparison as the others I have assumed that to increase the yield by 4,000,000 gallons daily the same proportionate increase in land area should be secured.

Cost of Changes and Operation.—The estimated cost of

adapting the Netherwood plant to conform to the same standards as the proposed new plants is as given in Table XXI.

TABLE XXI.

Capacity of Plant. Gallons daily.	Cost of Construction.	Annual Cost of operation.	Cost of water per 1,000 gallons.
4,000,000	$ 737,000.00	$86,400.00	5.9 cents.
8,000,000	1,032,000.00	132,000.00	4.5 cents.

A statement of the items considered in making this estimate will be found in Appendix E.

A comparison of these estimates with those for the proposed new well supply, shows that even without taking into account the values of franchises, and property properly a part of the investment of the company, the existing supply could not be adapted to the needs of Plainfield and made to conform to the same standards as the proposed new supplies for a less total investment or less annual expense than would suffice to secure a new supply independently of that of the Plainfield-Union Water Company.

PART X.

Comparison of the Different Supplies.

In order to determine the relative advantages and disadvantages of the different supplies, it is necessary to compare these with each other on the basis of:

1. The quality of the water in its natural state and as altered by purification.
2. The time required for their construction.
3. The cost of constructing and operating the works.
4. The relative advantages and disadvantages of a municipally-owned supply, as compared with the execution of a contract with the Plainfield-Union Water Company for a further term of years.

Comparison as to Quality.

Cities are no longer satisfied with inferior waters for municipal supplies. The requirements have risen markedly in recent years, since it has been realized how easy it is to secure good water and how small the extra cost.

Pure water does not exist outside of laboratories; relatively pure waters, only, can be had for municipal supplies and hence approximate, or tentative standards are necessary by which the relative purity can be judged.

It is not possible to fix absolute standards to which all waters shall conform, but certain constituents, which are harmful to health, or indicate a state of pollution from dangerous sources, enables judgment to be passed upon the suitability of the water for different uses. The main constituents which serve as a guide in this way are technically designated as the turbidity, color, hardness, alkalinity, incrustants, chlorine, odor, taste, bacteria and microscopic organisms of various sorts.

Turbidity.—Turbidity is imparted to waters by visible finely comminuted matters in suspension, and is distinct and different from color, although the turbidity itself is of different colors. Generally speaking, matters which cause turbidity are insoluble, or slowly so, in the water. Turbidity is measured by determining the weight of the particles in unit weight of water and is expressed as parts per million by weight. The ordinary method of measurement is to compare, optically, the turbidity of the water with standards prepared from distilled water with known weights of very finely powdered silica. By matching the sample with the proper one of a series of prepared standards the turbidity of the sample can be read with sufficient accuracy for practical purposes. In water with a turbidity of seven, a pin can be seen at a depth of 3 feet 7 inches,

while if the turbidity were 100 the p
a greater depth than 4 inches. A
would not ordinarily be noticed in a w

Color.—Color is imparted to wat
derived from contact with the soil,
posing organic matter of various sort
nificance except as making the water
Color, like turbidity, is usually meas
with arbitrarily established standards
mineral salts which give the same tc
that acquired naturally by the water i
ily used scale a color of 20 is not
tionable, although this could not be
becoming decidedly noticeable.

Hardness.—Hardness is the term
destroying power of a water, and is
of lime and magnesium in the wat
of carbonates and sulphates. The c
the analysis as "alkalinity," or the l
scale in boilers; the sulphates are
or the hardness that makes hard s
gether they form the total hardness.

Commercially, hardness is expen
ers, requiring large quantities of s
to neutralize the hardness before th
Roughly speaking, each part per
the consumer about 10 cents in soap
of water; or, in Plainfield, with a s
daily, about $14,600.00 worth of soa
in softening the water before the so

No absolute standards of hard
water which would be considered l
be considered soft in another. As s
ing may be assumed to represent ord
degrees of hardness:

Soft water	....
Hard water	....
Excessively hard water	.....
Mineral waters	....

Chlorine.—Chlorine represents
ses and is significant only when it i
of sewage pollution of the waters,
large enough amounts to affect inju
of steam boilers. In the present c

TABLE XXII.

Waters in Their Natural Condition.

	A. Gravity Lamington River Supply.			B. Gravity Raritan River Supply.			C. Pumped Raritan River Supply.			D. Pumped Passaic River Supply.			E. New deep well Supply.			F. New deep well Supply.			G. Present Netherwood Supply.
	Min.	Avg	Max.	Min.	Avg	Max.	Min.	Avg	Max.	Min.	Avg	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	
Turbidity	1	10	2000	1	15	3000	5	30	3000	15	40	3000	0	0	0	0	0	0	0
Color	3	10	20	2	10	20	3	8	15	10	20	40	0	0	0	0	0	0	0
Hardness	3	15	60	3	12	50	3	15	60	3	15	60	60	65	75	150	155	160	100
Alkalinity	2	12	50	2	10	45	2	12	50	2	12	50	55	60	65	105	110	115	98
Incrustants	1	3	10	1	2	5	1	3	10	1	3	10	5	5	10	45	45	45	2
Chlorine	2	3	4	2	3	4	2	3	4	3	4	6	8	10	12	7	8	9	6.5
Odor	Faintly veg.			Distinctly veg.			Distinctly veg.			Distinctly veg.			none.			none.			none.
Taste	Faintly veg.			Distinctly veg.			Distinctly veg.			Earthy & veg.			none.			none.			none.
Possibility of algae growths.	Slight			Slight			none.			strong.			none.			none.			none.
Sanitary quality	Hardly satisfactory.			Not satisfactory.			Not satisfactory.			Not satisfactory.			satisfactory.			satisfactory.			satisfactory
Quality for boiler purposes.	Good.			Good.			Good.			Good.			Good.			Not satisfactory.			Fair.

nificance, as none of the sources shows high enough chlorine contents to look suspicious or cause injury to boilers.

Odors and Tastes.—Waters of rivers and lakes usually acquire peaty and vegetable odors more or less intense in proportion to the conditions favoring such phenomena. The nature of the catchment area as well as of the reservoir in which the water is stored affect these qualities greatly. They are acquired from the same conditions that produce color and also from algae and other organisms, microscopic as well as of relatively large size, which live in, or die, in the water.

Bacteria.—The numbers of bacteria per cubic centimeter of water are indicative of the purity or pollution of the water from a sanitary standpoint, and may, or may not, give an idea of its safety for potable uses. High numbers of bacteria, with the persistent presence of organisms characteristic of intestinal discharges, would, if sewage pollution were known to be a probability, be considered an indication of pollution of a dangerous nature.

For convenient comparison, the different supplies have been arranged in Tables XXII and XXIII, respectively, in a way to indicate the salient features of each water in its natural state and also the probable conditions of each of the waters after receiving proper treatment.

Viewed in the light of the foregoing standards none of the waters, with the exception of that contemplated under Plan E is entirely satisfactory from all standpoints in its natural condition, but all can be brought to practically the same standard of acceptability by simple and well known methods of purification.

After treatment, supplies A, B, C and D would stand on equal terms and would be better than E, F and G by reason of being softer. The difference, however, would be slight, so far as the observations of the consumers would be concerned, and would not be sufficient to outweigh considerable differences in cost of construction, or in the cost of treating the water to secure the degree of purity noted. Hence, on the score of quality, there would be no great choice as between the natural waters, consideration of cost aside. In its natural condition, the Lamington River water approaches most nearly the requirements of a satisfactory water, but its occasional roiliness, liability to slight accidental pollution from sewage and surface drainage and somewhat earthy or vegetal taste would necessitate rapid filtration and the possible occasional use of bleaching powder to render it entirely satisfactory at all times.

The same is true with regard to the Raritan supply from the highlands, although, in this case the possibility of occas-

TABLE XXIII.

Waters After Proper Treatment.

	A. Gravity Lamington River Supply.			B. Gravity Raritan River Supply.			C. Pumped Raritan River Supply.			D. Pumped Passaic River Supply.			E. New deep well supply. (Soft water)			F. New deep well supply. (Hard water)			G. Present Netherwood supply.
	Min.	Avg	Max.	Min.	Avg	Max.	Min.	Avg	Max.	Min.	Avg	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	
Turbidity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Color	1	5	10	1	5	10	2	6	10	5	10	20	0	0	0	0	0	0	0
Hardness	3	15	60	3	12	50	3	15	60	3	15	60	60	65	75	55	55	55	45
Alkalinity	2	11	45	2	8	40	2	13	52	2	13	52	55	60	65	10	10	10	40
Incrustants	1	4	15	1	4	10	1	2	8	1	2	8	5	5	10	45	45	45	5
Chlorine	2	3	4	2	3	4	2	3	4	3	4	6	8	10	12	7	8	9	6.5
Odor	none.			none.			none.			none.			none.			none.			none.
Taste	none.			none.			none.			none.			none.			none.			none.
Possibility of algae growths	none.			none.			none.			none.			none.			none.			none.
Sanitary quality	satisfactory			satisfactory			satisfactory			satisfactory			satisfactory			satisfactory			satisfactory
Quality for boiler purposes	very good.			very good.			very good.			very good.			very good.			good.			good.

ional pollution from matters of sewage origin is greater. For this water, therefore, more thorough filtration is required than for the Lamington River water, the difference between the two types of plant adaptable to each water being in method of construction rather than operation excepting that the Lamington River water would not require so much coagulant as the other.

The pumped supplies from the North branch of the Raritan at North Branch Station and the Passaic at Berkeley Heights are both muddier and less pure than the two gravity supplies and would, therefore, cost more for purification.

All the ground-water supplies are satisfactory in every respect but hardness, and this can be corrected by proper treatment.

Comparison as to the Time Required for Construction.

As the City of Plainfield must either renew its contract with the Plainfield-Union Water Company, or construct a municipal plant and have it in readiness to supply water by May 2nd, 1912, the time required for constructing a new water supply system becomes of great importance in reaching a decision as to which supply is the best for adoption.

The time is short, at best. Assuming that a decision were to be reached during the coming winter or early spring to build a municipal plant, there would be available about one year for construction purposes. In my judgment it would not be possible to build any of the gravity supplies bringing water from a distance in that time, unless a contractor of unusual ability were secured and unless everyone connected with the inauguration of the works, including the Common Council, the city's legal department, the right-of-way agents, the financial supporters, and the entire executive force, exerted a degree of alertness and promptness seldom found in any except private undertakings. There is usually much formality to be observed in public undertakings and rapid work on large contracts is not ordinarily attainable. It would be difficult to get a contractor to push work, on these long pipe lines, owing to the heavy expense for plant, superintendence and administration that this would involve and from past experience I should consider two full working seasons as necessary to complete either of the gravity supplies. The pumped supply from North Branch, if work could be started early in the spring, could be completed in one season, as could either of the ground water supplies or the supply from the Passaic.

This consideration, therefore, practically rules out the gravity supplies unless the Plainfield-Union Water Company would

furnish water to the city at fair rates until the new plant could be completed.

Comparison as to Cost of Construction and Operation.

It is not always the plant which can be built for the smallest capital outlay that represents the best investment. Frequently works which bring water in by gravity from relatively great distances can be operated less expensively than a pumped supply obtained from sources nearer at hand. In order to determine the relative advantages of the different plants proposed as feasible, careful estimates of cost of construction and operation have been prepared, and abstracts thereof are given in some detail in Appendix E.

The elements that must be considered in comparing these different supplies on the basis of cost are:

1. The cost of construction.
2. The annual cost of operating the works.
3. The interest charges on the capital invested.
4. The depreciation which takes place in parts of the plant as the result of age and replacement for one cause or another.

Basis of Estimates.—In estimating the costs of the different plants, liberal allowances have been made for the purchase of the land necessary to construct the reservoirs and other parts of the works including rights-of-way for pipe lines. Allowances have also been made to compensate for damages those riparian owners whose rights in the waters of the different streams would be interfered with by the taking of the water for Plainfield. All the items in the estimates carry a margin of 15% above contract cost to cover engineering and contingencies. It would be impracticable to give here the detailed calculations on which these estimates of cost are based; each item has been arrived at after careful consideration of all the conditions, using current prices for labor, and for materials, which would be delivered at the nearest railroad station and redistributed from there to the various places required for the construction of the works.

Considerable trouble has been taken to secure reliable and conservative prices for all machinery and for its erection in a first-class manner.

In making the estimates of the annual cost of operation, interest has been figured upon the investment, in each case at the rate of 5% per annum.

No sinking fund allowance has been provided, but amounts have been incorporated in the annual cost of maintenance to cover the amount of depreciation due to age and ordinary wear and tear expected in the different parts of the plants. These

sums covering depreciation have been made up of annuities, or equal annual payments distributed over a number of years, the annuities being sufficient in amount to reproduce the cost of the various parts of the plants by the time that they will have become worn out, antiquated or require replacement to make room for more modern or more efficient parts. These annuities have been based upon assumed lengths of life of the different parts of the plant in accordance with the schedule given in Table XXIV.

TABLE XXIV.

DEPRECIATION TABLE.

Items.	Assumed length of life.	Annuity on each thousand dollars of valuation.
Masonry conduits	Permanent	......
Covered masonry filters	"	......
Covered masonry reservoirs	"	......
Permanent buildings	100 years	$ 1.65
Cast iron pipe	80 "	3.11
Vitrified pipes	80 "	3.11
Gate houses	65 "	5.00
Wooden pipe lines	50 "	8.87
Steel pipe lines	35 "	16.54
Valves, etc.	35 "	16.54
Engines and pumps	30 "	21.02
Boilers	20 "	37.22
Minor machinery	20 "	37.22

By the provision of an item for depreciation, based upon the above assumed lengths of life, a sufficient sum of money is added to the yearly cost of operation to equal, at 3% compound interest, the value of the different works during the assumed life of each part. This provides for keeping the plant constantly up to date and in effective service.

The annual cost of operating the works includes fuel, power, light, labor, supplies and all necessary expenses about the various plants for pumping and purifying the waters. In connection with the gravity supplies and long pipe lines, items, estimated to be sufficient to provide for patroling the watershed, policing the property and caring for the right-of-way, valves, etc., on the long pipe lines between the head works and the Plainfield reservoir, have been included.

An item of $5,000.00 per annum has been included in each

estimate to cover the cost of repairing leaks, repairing pavements, maintenance of the pipe line shop, repairing valves and hydrants and other expenses usual in connection with the maintenance of street mains in a city the size of Plainfield. There has also been included an allowance of $4,000.00 per year to cover the cost of supervision and general office expenses connected with the administration of the department. It is believed that all the estimates are ample to cover the cost of the work contemplated in each case and that a comparison will truly show the relative merits of the different plans, from the point of view of construction and operation.

Summaries of Estimates of All Supplies.—Summaries of the estimates of cost of construction and operation are given in Tables XXV and XXVI, respectively.

SUMMARY OF ESTIMATES.

TABLE XXV.

Costs of Construction.

Supply.	Capacity of Works. Gallons per day.	
	4,000,000	8,000,000
A. Gravity filtered supply from the Lamington River.	$1,161,000	$1,374,000
B. Gravity filtered supply from the North Branch of the Raritan River.	1,325,000	1,531,000
C. Pumped, filtered supply from the North Branch of the Raritan River.	1,009,000	1,177,000
D. Pumped, filtered supply from the Passaic River.	805,000	973,000
E. New deep well supply from vicinity of Plainfield if soft.	714,000	962,000
F. New deep well supply from vicinity of Plainfield, softened.	841,000	1,113,000
G. Extension of present supply.	737,000*	1,032,000*

*Franchise rights not considered; see explanation of estimate in Appendix B.

TABLE XXVI.

Annual Costs of Operation.

Supply.	Capacity of Works. Gallons per day.			
	4,000,000		8,000,000	
	A.	B.	A.	B.
A. Gravity filtered supply from the Lamington River.	$80,000	$55,00	$94,000	$32.00
B. Gravity filtered supply from the North Branch of the Raritan River.	91,000	62.00	106,000	36.00
C. Pumped, filtered supply from the North Branch of the Raritan River.	93,000	64.00	134,000	46.00
D. Pumped, filtered supply from the Passaic River.	81,000	55.00	116,000	40.00
E. New deep well supply from vicinity of Plainfield, if soft	67,000	45.00	100,000	34.00
F. New deep well supply from vicinity of Plainfield, softened	87,000	59.00	133,000	45.00
G. Extension of present supply.	*86,400	*59.00	*132,000	*45.00

*See explanation of estimates in Appendix E.

In columns "A" are given the annual costs of operation and maintenance.

In columns "B" are given the cost of the water, per million gallons, delivered into the street mains in Plainfield. These prices, ranging from $32.00 to $64.00 per million gallons, are all moderate, and within the limits of usual experience. The schedule of rates now in force in Plainfield permits the Water Company to charge for metered water at the rate of $250.00 per million gallons.

The City of New York has, of late, been selling water at cost, stated to be $130.00 per million gallons, to several cities and towns in Westchester County.

Comparisons.—Of the two gravity supplies investigated, that from the Lamington River, although secured at a greater distance than the one from the North branch of the Raritan, would be the better and cheaper both in cost of construction and cost of operation; and also the Lamington River supply is better than the other in point of quality, and would take no longer to construct. Either of these supplies could be increased to yield over 8,000,000 gallons daily, but that from the Lamington River could be developed to a considerably higher limit than the one from the North branch of the Raritan. Plan B, representing the supply from the Raritan River can, therefore, be eliminated from further consideration.

Between the pumped river water supplies, Plans C and D, the main difference would be that Plan C could be developed to yield a much larger quantity of water than 8,000,000 gallons daily if required, while Plan D would be practically limited to that amount by the extreme dry weather flow of the river. The difficulties to be expected in connection with the operation of the Passaic River plant would be much greater than of the plant on the Raritan River, owing to the large amount of amorphous matter in the Passaic River water which would have a tendency to cause more frequent clogging of the filters, and consequently would necessitate greater care in the operation of the plant. As between the two supplies I would consider that the advantages which the North Branch supply exhibit over the Passaic supply would outweigh the difference in cost of construction and operation as shown by these estimates. This being the case, preference would still be given to the Lamington River gravity supply as the cost of construction of the pumped and filtered supply from the North branch of the Raritan would be almost as great as that of the gravity supply, and the operation of the pumped and filtered supply would introduce several complications that would not have to be contended with in the gravity supply.

This leaves for final comparison only the supply from the Lamington River, and the supplies that could be derived from ground water in the vicinity of Plainfield. If fortunate conditions should make possible the development of a supply such as is represented under Plan E, collected from deep wells in the sandstone formation in the vicinity of Plainfield of a water as clear, pure and soft as that produced by the well in the Spicer Manufacturing Company's plant, there would be no question as to which plant to choose, as the cost of developing

the ground water supply would be much less than that of the gravity supply, and the annual cost of operation for the 4,000,000 gallon installation less, and for the 8,000,000 gallon installation no more than for the gravity supply. In case the water found in establishing a ground water supply should prove to be as hard as that of the Spicer Manufacturing Company's well in South Plainfield, then the cost of construction would still be less, but the annual cost of operation somewhat more than for the gravity supply, and judged from the standpoint of cost alone the gravity supply from the Lamington River would be preferable.

Summary.—Of all the new possible sources of supply investigated, therefore, the situation may be summed up as follows:

If a supply of ground water soft enough for use without treatment can be developed in the neighborhood of Plainfield, then such a supply would cost less for construction and operation than the gravity supply from the Lamington River, but if the ground water supply requires softening, then the supply from the Lamington River would be the cheaper in cost of operation, although about 40% more expensive to build.

Comparison of New Supply With Netherwood Supply.—For purposes of comparison, I have also prepared an estimate, designated "6" in the tabulated summaries, showing the approximate cost of improving and extending the present water supply plant of the Plainfield-Union Water Company at Plainfield so as to furnish a supply comparable in quality and quantity with that provided for in the estimates for the new supplies. This has been done to show that Plainfield could not afford to purchase the present Netherwood plant as a municipal investment. An inspection of the estimates will show that, while apparently a somewhat less expense would be required in improving and extending the Netherwood plant than would be required for the construction of an entirely new well plant, there would be no advantage accruing to the city from acquiring the present plant, under the valuation assumed, for the reason that there would be no advantage, in point of annual expense, as compared with the construction of a new plant. The reasons for this are:

a. The costs of construction given in the table do not include any sums for the value of the franchise rights of the Plainfield-Union Water Company, which rights would be seriously interfered with by the taking of the pumping plant by condemnation proceedings.

b. There is not included in this cost of construction a sum representing the value of the acquired income of the company due to its having established a paying business in Plainfield.

c. There are not included in the costs of construction sums to represent the proportional part of the total investment made by the Plainfield-Union Water Company in connecting mains between the Netherwood pumping station and other municipalities.

d. Sums are not included to represent the damage that would be done to the company by depriving it of its source from which it supplies the other communities under contractual relations.

The purchase or acquisition by condemnation of the Netherwood pumping station could not be contemplated by the City of Plainfield, unless she were in a position to take over the entire business done by the Plainfield-Union Water Company growing out of the sale of water from the Netherwood source, and this would involve so many complications that serious consideration of it is unnecessary.

Impossible to Acquire Netherwood Plant.—If sums representing the present value of all the rights above specifically mentioned and others which have not been mentioned, were to be included in the construction cost as representing the value upon which the plant should earn an income, the cost of acquiring the Netherwood plant and treating the water to make it comparable with those of the other supplies under consideration would be prohibitive.

Alternatives Open to City.—So far as the establishment of a municipal plant is concerned, therefore, the only choice for Plainfield on the basis of cost, would lie between the development of a ground water supply near at hand or the development of a gravity supply from the Lamington River.

Comparison Between Municipal Ownership and Purchasing Water By Contract from the Plainfield-Union Water Company.

The foregoing investigations have shown that Plainfield can, in a number of ways, secure and operate a water supply plant independently of the Plainfield-Union Water Company and can supply soft water of high purity and attractive appearance to its citizens for an annual expense no greater, to say the least, than would be required to enable the Plainfield-Union Water Company to earn a fair return on its investment if supplying Plainfield with water of equal quality and quantity.

They have also shown that additional water for future extensions can be secured by the Water Company, and that the water now furnished by the company can be rendered more suitable for use, as to hardness, than the present supply. The

question, therefore, resolves itself finally into a consideration of several propositions, as follows:

What would be the city's best course,

1. If the Plainfield-Union Water Company would enter into a new contract with the City of Plainfield in which provisions were to appear that would guarantee to Plainfield under enforceable indemification provisions, a supply of soft water of quality satisfactory for all purposes, in quantity and at a pressure sufficient for all needs, with provisions for increasing the quantity in reasonable advance of actual requirements, and with storage locally of sufficient quantity of water in an elevated distribution reservoir to provide a reserve to balance the fluctuations in draft, and if the company would render this service at the rates of charges provided for in the schedule at present in force.

2. If the company would enter into a new contract with Plainfield, as above outlined, except'ng that a material advance in rates be granted.

3. If the company would enter into the contract as proposed above, except as to softening the water, without increasing the rates.

It is, of course, impossible to anticipate the exact replies which would be formulated by the Water Company to these questions, but an analysis of what would be required in order to comply with the conditions will show what would lie within or without the range of possibility.

Capacity of Netherwood Plant.—The present plant, which is drawn upon as needed, for the supply of Westfield, Cranford, Roselle and Elizabeth, in addition to Plainfield, has just about sufficient capacity to take care of Plainfield's present needs, with a fair reserve capacity for emergencies and to provide for growth of population until new extensions can be completed. In order that all the communities supplied may have satisfactory service, therefore, additional water must be provided at once, in an amount sufficient to take care of the consumption of all the other communities outside of Plainfield, so that the Netherwood source could be reserved for Plainfield; preparations should also be made for a still further extension of the Netherwood supply to take care of the future growth of Plainfield for a reasonable number of years.

Improvements Proposed.—The improvements now under way at the Netherwood plant give promise of an increase in quantity, the amount of increase being, as yet, unknown.

It is also said that land has been purchased on the mountain for a reservoir site which, if availed of, would improve matters with respect to pressures in times of maximum draft, providing large enough connections between the street mains and this reservoir were laid. No plans are made, or contemplated,

for softening the water, so far as I know, and I have been informed that the water secured from the new deep wells, (which is not yet available for use) is not so soft as the water now supplied from the Netherwood wells.

From this showing it would seem that for the company to live up to the proposed agreement it would have to arrange to soften the supply, purchase additional land for extra wells, probably change the system proposed for pumping the new wells to a more elastic and more economical plan and take rapid and definite steps to secure additional water for the other towns now depending wholly or in large part on the Netherwood wells.

Whether or not the company could undertake expenditures to guarantee such service, only its officials know; but, whether it could, or not, the city could secure satisfactory service by building its own works and operating them at an annual expense no greater than the city and water consumers in Plainfield now pay for water to the Plainfield-Union Water Company.

Cost of Making Desirable Improvements to Netherwood Plant.—The carrying out at the Netherwood plant of the improvements mentioned, would call for an expenditure of about $335,000.00 at present, and about $300,000 more when the capacity has to be extended to 8,000,000 gallons daily; and would increase the annual operating expenses at present by about $100.00 per day or $25.00 per million gallons.

Higher Rates Necessary.—Unless the rates were increased to cover this, it is probable the company's business could not stand the additional load, as the excuse given for extending its mains to the east, and supplying other communities, was that it could not secure enough revenue in Plainfield and North Plainfield to make the business profitable. I believe, from what information I have been able to secure, that the company could not afford to make these desirable improvements unless the rates were to be raised about 20 per cent. above those now prevailing.

If however, the softening of the water were dispensed with the additional investment for the reservoir, connecting mains, and additional land for new wells, would amount to about $165,000.00 at present, and the annual operating expenses would be increased by about $8.00 per million gallons.

Generally speaking, therefore, the indications are that without raising the water rates, the company could not afford to render the class of service that the city could secure for itself at the present rates, but could afford to comply with all reasonable requirements except that of supplying soft water.

Alternatives Open to City.—Summarizing the situation briefly, it may be said, then, that the alternatives which are open to the city are:

1. To build and operate its own water works, supplying the inhabitants of Plainfield with pure, soft water at an annual cost for operation and maintenance which would not require higher water rates than now prevail and at a construction cost within the means of the city. This would involve the laying of new street mains, or the purchase or condemnation of the Plainfield-Union Water Company's water mains in Plainfield, providing the cost of acquiring these did not exceed the cost of laying a new set of street mains, but would leave the Water Company in possession of its sources of supply and rights to lay mains in the streets of Plainfield.

2. The arrangement of a new contract with the Water Company under which the Water Company would be held to furnish as good service, as to quantity, quality, and pressure as the city could secure of its own efforts, arranging with the company, if soft water be furnished, to pay somewhat higher rates, the additional amounts to be agreed upon between the city and company after an investigation as to the proper amount of increase to be allowed therefor.

3. The arrangement of a new contract with the Water Company under which the company would be held to furnish as good service as to quantity, pressure and quality, except as to hardness, as the city could secure of its own efforts, the rates to remain practically as at present.

In reaching a decision as to the best policy to be adopted in this matter, the following should be considered:

Considerations to be Kept in View.—The Water Company has invested a large amount of money in its plant and has, with very few exceptions, given fair service in the past. In investing its money it carried a loss on the business in early years, as do all water companies situated as this one was; for this the company is entitled to consideration as the city has thereby been saved this loss and the necessity of carrying a bonded debt for water works for many years.

The rates the company has received have been investigated by more than one commission always with the result that the charges have not been considered unfair compared with those received for similar service in other cities where conditions are comparable.

The water which has been furnished from the Netherwood plant has been accepted without complaint by the majority of the consumers.

Contract Advantageous.—If a satisfactory contract could be arranged, by which the city could be assured, not by promises, but by the existence of a good plant with proper reserve capacity for emergencies, of a satisfactory supply for the present

and for a reasonable period in the future, it would, under the circumstances, be advantageous to both the city and the Water Company.

The city is in a position, however, to exact fair service and good water, as it can, in the time available, build its own plant and be independent of the Water Company in every way.

Shortage of Water.—There have been times, in the past, particularly during July of the present year, when the Water Company nearly exhausted all its available sources of supply and the communities supplied by it were inconvenienced for lack of water and failure of pressure, and some even were furnished water unfit for consumption.

The company's policy has not, in emergencies, protected its consumers heretofore, and cannot be depended upon to do so in the future in times of dry weather as the plant has no reserve capacity to take care of unusual conditions, and is not likely to have, if it be possible, by squeezing through from year to year to postpone the spending of large sums of money for extensions.

Netherwood Supply Cannot be Reserved for Plainfield Only.—As Plainfield is only one of the many communities supplied by this company, the company cannot, unless it develops a large and independent supply for its other consumers, reserve the Netherwood plant entirely for the use of Plainfield. In case of a severe drought, such as was experienced last summer, when all their sources of supply were heavily taxed, it would be impossible for the company to reserve the Netherwood source entirely for Plainfield when the other towns on the company's mains were suffering for water; consequently Plainfield would have to suffer a water shortage whenever there was a general deficiency of supply.

Suburban Water Companies in General.—This aspect of the case is really more grave than it appears on its face. The underlying principle in the organization of suburban water companies, like the Plainfield-Union, is that the consolidation of these smaller companies permits a smaller total outlay for plant and a smaller organization for operation than would be required for the separate plants. By having fewer sources of supply, of larger capacity, and inter-connecting mains, water can be sent from any part of the system to make up deficiencies in another part, and, theoretically, better service can thus be rendered to the consumers by this arrangement. The difficulty is, however, that under such an organization, the elasticity of the plan of operation conduces to the postponement of extensions until conditions become so unendurable that in order to placate the dissatisfied consumers some sort of a show of ac-

tivity has to be made. The company, therefore, will periodically resort to half-baked plans and to emergency expedients to increase the supply; cut-off pressure, rebate water bills for lawn sprinkling to conserve the supply, cry out about enormous waste, lay the blame on unusual conditions, or acts of Providence, and promise anything and everything until the acute trouble passes over. When, with the passing of the hot weather the consumption decreases and the supply again naturally increases matters gradually relapse into the regular routine, and the company lets extensions go over for another year or two, gambling on the probability that for two or three years following the conditions will probably not be so acute.

It is but natural that this viewpoint should be taken by a company operating a system of this kind. Increased investments without gaining increased revenues therefrom cut down dividends, and the duty of the directors and officers of the companies is to protect the property and limit the expenditures to necessities. Too frequently this side of the matter only is given consideration by the officers of the company, the interests of the consumers being relegated to the background until forced forward by revolt. The policy is a foolish one, which experience always explodes. Many a company has been reduced to the verge of dissolution by it and many more will be.

Confidence Necessary to Execution of Contract for Service.—If Plainfield executes another contract with the Water Company, it can, of course, consider itself as only one community among many that this company is bound to serve under its contracts; and whether or not Plainfield should make such a contract will depend on the confidence with which, irrespective of contractual obligations, the promises of the company can be accepted, and its ability to look ahead and provide for future needs in advance of the requirements be conceded.

Conditions Under Which City Should Establish a Municipal Plant.—It is, after all, a matter of confidence. It is doubtful whether a contract could be drawn up in advance that would protect Plainfield's interests if the company was not physically able or did not feel inclined, or could not afford, to live up to its terms. The rate at which extensions should be made and the times that they should be inaugurated, all depend upon the exercise of experienced judgment and the following of a wise policy of securing, in advance, the authorization and the funds wherewith to keep ahead of the requirements. Engineering ability of a high order, executive ability and foresight on the part of the management and ample financial resources, all are necessary in order to make the interests of the company and of the consumers meet, and if Plainfield, through its past ex-

perience, or through its general view of the relations of Plainfield and all the other communities now supplied with water by the Plainfield-Union Water Company, is not satisfied that the present company can and will, for many years in the future, provide for Plainfield's needs as well, and for a total annual expense approximately as small as that for which the city could establish and operate a municipal supply, then Plainfield can and should decline to enter into another contract with the company and proceed at once to establish a municipal supply.

JAMES H. FUERTES,
Consulting Engineer.

APPENDIX A

POPULATION AND WATER SUPPLY REQUIREMENTS OF PLAINFIELD

TABLE 1.

PUMPAGE FROM NETHERWOOD WELLS AND ESTIMATED WATER CONSUMPTION.

TABLE 2.

ESTIMATES OF POPULATIONS AND WATER CONSUMPTION.

TABLE I. (Appendix A.)

Pumpage from the Netherwood Wells and Estimated Water Consumption in Plainfield, N. J.

Year.	Total Pumpage. Million gallons daily	Delivered to east of Plainfield. Million gallons daily	Delivered to Plainfield and North Plainfield. Million gallons daily	Estimated Populations. Plainfield.	Estimated Populations. North Plainfield.	Estimated Populations. Plainfield and North Plainfield combined.	Estimated average daily consumption of water in Plainfield only. Million gallons	Per capita consumption in Plainfield. Gals. daily
1895	1.695	.945	.750	13,629	4,245	17,874	.572	42
1896	1.455	.756	.699	13,950	4,400	18,350	.530	38
1897	1.610	.846	.764	14,260	4,550	18,810	.580	41
1898	1.500	.668	.832	14,650	4,700	19,350	.630	43
1899	1.710	.698	1.022	15,000	4,850	19,850	.770	51
1900	1.985	.944	1.041	15,367	5,009	20,378	.785	52
1901	1.845	.833	1.012	15,900	5,010	20,910	.768	48
1902	1.965	.798	1.167	16,500	5,011	21,511	.894	54
1903	2.270	.840	1.430	17,200	5,013	22,213	1.105	64
1904	2.875	1.235	1.640	17,800	5,014	22,814	1.271	71
1905	3.040	1.447	1.593	18,468	5,016	23,484	1.260	68
1906	3.440	1.637	1.803	19,100	5,100	24,200	1.420	74
1907	4.055	1.753	2.302	19,850	5,200	25,050	1.822	92
1908	2.937	1.587	2.350	20,500	5,400	25,900	1.868	91
1909	4.171	1.642	2.529	21,200	5,700	26,900	1.993	94
1910	3.921	*.....	*.....	22,000	6,000	28,000	.....	..

*Data incomplete.

TABLE II. (Appendix A.)

Estimated Population and Water Consumption, Plainfield, N. J.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Year.	Population.	Per Capita Consumption.	Average Daily Consumption.	Maximum Daily Consumption.	Excess of maximum hourly rate, at 60 gallons daily per capita.	Maximum hourly rate.	Number of fire streams required.	Allowance for fire service.	Extreme maximum hourly rate including fire service.	Allowed maximum hourly rate including reasonable fire service.
		Gallons daily.	Million gallons.	Million gallons	Million gallons. daily.	Million gallons daily.		Million gallons daily.	Million gallons daily.	Million gallons daily.
1910	22,000	85	1.87	2.92	1.32	4.24	12	3.89	8.13	6.91
1920	30,000	90	2.70	4.22	1.80	6.02	14	4.54	10.56	8.98
1930	40,000	95	3.80	5.94	2.40	8.34	16	5.18	13.52	11.49
1940	55,000	100	5.50	8.59	3.30	11.89	19	6.15	18.04	15.33

APPENDIX B

TABLE I.

YIELD OF NETHERWOOD WELLS AND RECORD OF GROUND WATER LEVELS.

TABLE II.

LIST OF DEEP WELLS IN EASTERN NEW JERSEY IN THE RED SHALE FORMATION.

TABLE III.

RAINFALL RECORDS OF NEW BRUNSWICK, PLAINFIELD, SOMERVILLE AND SOUTH ORANGE.

WATER CONTRACT BETWEEN THE CITY OF PLAINFIELD AND THE PLAINFIELD WATER SUPPLY COMPANY. DATED MAY 2ND, 1892.

NOTE: To reduce the elevations of the water in the Netherwood wells, as given in the last column of Table I, to sea level, add 53.76 feet.

NOTE: The data regarding driven wells Nos. 1 to 42-A, given in Table II, were supplied by Stotthoff Brothers, Flemington, N. J. Data for the other wells listed were compiled from various sources, principally the annual reports of the Geological Survey of New Jersey.

TABLE I.

Yield of Wells, and Ground Water Levels, at the Netherwood Pumping Station.

Year.	Month.	Total Pumpage. Gallons.	Pumpage to East of Plainfield. Gallons.	Level of water in wells.
1891.	Sept.	3,473,702		49.11
	Oct.	3,158,735		49.22
	Nov.	2,470,607		
	Dec.	5,509,011		48.90
	Totals	14,612,055		
1892.	Jan.	4,312,403		52.00
	Feb.	4,100,037		51.19
	March	11,969,335		52.05
	April	5,561,785		51.23
	May	6,384,747		50.46
	June	8,185,280		49.80
	July	10,191,236		48.98
	Aug.	12,172,795		47.65
	Sept.	27,207,179		46.25
	Oct.	50,464,318		44.52
	Nov.	48,348,417		43.77
	Dec.	43,303,809		43.55
	Totals	232,201,336		
1893.	Jan.	45,532,430		43.40
	Feb.	24,843,708		45.96
	March	30,325,853		50.10
	April	35,803,369		50.86
	May	35,011,236		52.01
	June	29,718,851		50.15
	July	41,455,875		47.78
	Aug.	46,511,585		46.84
	Sept.	29,273,138		46.39
	Oct.	41,738,298		44.04
	Nov.	51,175,811		44.61
	Dec.	49,615,267		45.75
	Totals	461,005,421		
1894.	Jan.	37,412,345		45.25
	Feb.	32,400,018		46.14
	March	33,304,680		48.80
	April	32,617,092	18,943,500	49.35
	May	35,849,527	16,528,500	47.20
	June	43,679,846	24,740,250	46.50
	July	63,715,874	35,628,000	44.62
	Aug.	64,139,217	36,211,500	43.05
	Sept.	68,913,068	48,122,250	42.75
	Oct.	54,059,501	37,629,750	42.92
	Nov.	75,455,161	32,769,000	44.35
	Dec.	42,394,330	24,881,000	44.90
	Totals	583,940,659	275,453,750	
1895.	Jan.	42,277,189	25,452,000	46.89
	Feb.	38,987,049	21,054,000	46.75
	March	39,795,967	22,224,000	47.20
	April	43,258,321	25,922,250	47.77
	May	42,074,061	19,971,000	46.52
	June	51,676,764	22,161,750	45.32
	July	50,743,439	24,117,000	43.92
	Aug.	75,542,561	42,191,500	41.92
	Sept.	76,464,225	42,702,000	40.80
	Oct.	67,099,329	43,398,000	40.58
	Nov.	36,730,271	20,174,250	40.73
	Dec.	55,046,334	36,226,500	39.78
	Totals	619,695,510	345,594,250	

Year.	Month.	Total Pumpage. Gallons.	Pumpage to East of Plainfield. Gallons.	Level of water in wells.
1896.	Jan.	57,047,245	37,218,000	39.20
	Feb.	49,001,805	30,761,250	41.77
	March	53,808,029	33,313,500	43.80
	April	44,661,419	24,677,250	44.70
	May	49,928,818	22,918,500	43.80
	June	40,772,920	16,626,000	42.72
	July	51,785,957	25,359,000	42.35
	Aug.	50,749,578	23,380,500	41.63
	Sept.	40,657,973	20,224,500	41.38
	Oct.	37,883,396	19,921,500	40.80
	Nov.	29,461,950	11,856,750	40.62
	Dec.	30,715,774	10,128,000	40.18
	Totals	536,474,864	276,384,750	
1897.	Jan.	42,193,687	20,594,250	39.85
	Feb.	44,099,689	24,153,750	40.14
	March	59,613,483	36,185,250	40.92
	April	50,646,690	27,071,250	42.02
	May	55,015,300	31,134,750	43.48
	June	46,474,930	20,928,000	42.80
	July	66,541,390	33,070,000	43.77
	Aug.	52,963,950	28,725,000	46.40
	Sept.	46,104,160	23,217,750	46.00
	Oct.	37,764,030	16,598,250	45.30
	Nov.	42,100,250	22,800,000	44.05
	Dec.	45,742,340	24,870,750	45.10
	Totals	589,259,899	309,349,000	
1898.	Jan.	46,984,890	25,163,250	46.08
	Feb.	40,159,510	19,276,500	48.45
	March	40,218,840	17,865,000	48.40
	April	52,057,460	30,640,500	49.02
	May	39,661,960	15,775,750	52.80
	June	49,266,000	18,277,000	50.15
	July	55,349,750	25,064,000	49.10
	Aug.	45,251,040	17,889,000	47.88
	Sept.	49,877,830	20,006,250	46.85
	Oct.	45,505,630	20,427,000	45.70
	Nov.	40,851,720	17,175,750	46.82
	Dec.	42,609,100	17,147,250	48.70
	Totals	547,793,730	244,707,250	
1899.	Jan.	45,985,060	18,374,250	50.27
	Feb.	48,487,830	20,702,250	51.15
	March	45,873,880	18,228,000	56.00
	April	44,715,330	17,624,250	53.95
	May	51,450,570	19,361,250	51.60
	June	75,182,120	27,007,500	48.82
	July	73,203,590	36,441,000	47.30
	Aug.	56,564,500	24,316,250	46.65
	Sept.	46,961,890	17,560,500	45.92
	Oct.	49,368,120	18,161,250	45.40
	Nov.	44,469,900	19,255,500	45.25
	Dec.	44,277,290	18,228,750	44.45
	Totals	626,540,080	255,260,750	
1900.	Jan.	70,682,030	40,368,750	43.65
	Feb.	61,352,030	32,643,000	43.40
	March	50,241,200	22,178,250	47.25
	April	45,040,380	18,429,750	46.15
	May	51,099,420	20,163,750	46.80
	June	51,918,230	21,048,750	45.70
	July	77,312,420	37,101,750	43.50
	Aug.	73,265,080	27,251,750	41.80
	Sept.	74,501,720	38,783,750	40.80
	Oct.	65,827,100	36,125,750	41.05
	Nov.	48,230,150	22,053,000	40.80
	Dec.	55,727,680	29,007,000	40.20
	Totals	725,197,440	345,155,250	

Year	Month	Total Pumpage, Gallons	Pumpage to East of Plainfield, Gallons	Level of water in wells
[illegible]	[illegible]	[illegible]	[illegible]	40.5[illegible]
	[illegible]	[illegible]	[illegible]	35.[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	Nov.	[illegible]	[illegible]	[illegible]
	Dec.	[illegible]	[illegible]	[illegible]
	Totals	232,201,[illegible]	[illegible]	
[illegible]	[illegible]	45,532,430	[illegible]	[illegible]
	[illegible]	24,843,708	[illegible]	[illegible]
	[illegible]	30,325,853	[illegible]	[illegible]
	[illegible]	35,803,369	[illegible]	[illegible]
	[illegible]	35,011,236	[illegible]	[illegible]
	[illegible]	29,718,851	[illegible]	[illegible]
	[illegible]	[illegible]1,455,875	[illegible]	[illegible]
	[illegible]	[illegible]6,511,585	[illegible]	[illegible]
	[illegible]	[illegible]273,138	[illegible]	4[illegible]
	[illegible]	[illegible]298	[illegible]	44.0[illegible]
	[illegible]	[illegible]811	[illegible]	44.61
	[illegible]	[illegible]	[illegible]	45.75
	Totals	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	45.25
	[illegible]	[illegible]	[illegible]	46.14
	[illegible]	[illegible]	[illegible]	48.80
	[illegible]	[illegible]	18,943,500	49.35
	[illegible]	[illegible]	16,528,500	47.20
	[illegible]	[illegible]	24,740,250	46.50
	[illegible]	[illegible]	35,628,000	44.62
	[illegible]	[illegible]	36,211,500	43.05
	[illegible]	[illegible]	48,122,250	42.75
	[illegible]	[illegible]	37,629,750	42.92
	[illegible]	[illegible]	[illegible]2,769,000	44.35
	[illegible]	[illegible]	[illegible]4,881,000	44.90
	Totals	[illegible]	[illegible]5,453,750	
[illegible]	[illegible]	[illegible]	[illegible]452,000	46.89
	[illegible]	[illegible]	[illegible]054,000	46.75
	[illegible]	[illegible]	[illegible]224,000	47.20
	[illegible]	[illegible]	[illegible]922,250	47.77
	[illegible]	[illegible]	[illegible]971,000	46.52
	[illegible]	[illegible]	[illegible]161,750	45.32
	[illegible]	[illegible]	[illegible]117,000	43.92
	[illegible]	[illegible]	[illegible]191,500	41.92
	[illegible]	[illegible]	[illegible]702,000	40.80
	[illegible]	[illegible]	[illegible]98,000	40.58
	[illegible]	[illegible]	[illegible]74,250	40.73
	[illegible]	[illegible]	[illegible]26,500	39.78
	Totals	[illegible]	[illegible]4,250	

Year.	Month.	Total Pumpage. Gallons.	Pumpage to East of Plainfield. Gallons.	Level of water in wells.
1906.	Jan.	86,486,400	37,051,000	43.00
	Feb.	85,130,460	35,598,000	41.15
	March	95,992,260	44,294,500	42.85
	April	97,742,540	44,212,000	44.90
	May	104,369,330	48,330,400	44.45
	June	104,503,570	49,921,500	42.85
	July	99,980,640	41,387,450	42.05
	Aug.	117,141,000	60,962,250	40.80
	Sept.	122,914,380	65,803,250	39.80
	Oct.	109,400,370	54,283,750	38.70
	Nov.	106,748,760	52,662,500	38.40
	Dec.	125,785,850	62,821,500	36.30
	Totals	1,258,195,560	597,328,100	
1907.	Jan.	140,465,140	71,321,300	36.20
	Feb.	120,236,180	51,715,250	36.05
	March	123,243,860	56,169,000	37.80
	April	114,151,330	35,314,750	38.45
	May	127,183,500	64,465,000	38.30
	June	119,621,290	53,562,500	37.45
	July	140,648,620	61,345,250	36.05
	Aug.	139,532,030	62,178,250	34.85
	Sept.	123,824,380	54,623,750	34.65
	Oct.	114,270,850	44,193,000	32.65
	Nov.	106,095,850	42,029,750	35.20
	Dec.	110,978,770	43,333,000	36.55
	Totals	1,480,201,800	640,250,800	
1908.	Jan.	114,254,270	45,959,250	38.65
	Feb.	120,059,910	44,894,500	39.70
	March	113,994,550	45,858,000	41.80
	April	110,642,610	45,360,750	41.60
	May	115,308,360	48,834,750	43.35
	June	129,201,360	53,035,500	41.80
	July	139,801,180	58,357,500	40.25
	Aug.	126,786,550	52,643,500	39.35
	Sept.	119,627,990	47,684,750	38.15
	Oct.	120,391,620	47,398,250	37.30
	Nov.	110,502,370	43,914,750	36.00
	Dec.	116,303,350	45,594,700	34.70
	Totals	1,436,874,120	579,536,200	
1909.	Jan.	123,509,230	46,595,750	34.20
	Feb.	109,345,700	42,037,500	34.50
	March	116,626,920	44,453,750	36.30
	April	113,575,080	45,327,000	38.20
	May	122,229,900	48,919,500	38.90
	June	128,936,350	52,249,250	36.90
	July	168,779,340	64,480,000	34.05
	Aug.	144,434,460	56,183,500	33.85
	Sept.	126,015,690	50,835,250	33.10
	Oct.	124,208,000	49,753,250	32.45
	Nov.	117,637,790	49,700,500	31.40
	Dec.	127,236,730	48,805,750	30.40
	Totals	1,522,535,190	599,341,000	
1910.	Jan.	146,185,780	51,737,500	30.10
	Feb.	129,400,460	Meter moved to El Mora.	30.35
	March	130,532,710	Meter moved to El Mora.	32.50
	April	124,785,870	Meter moved to El Mora.	32.75
	May	89,328,900	Pumping from El Mora.	34.50
	June	95,431,500	Pumping from El Mora.	33.80
	July	154,820,870		32.25
	Totals	870,436,090		

Year.	Month.	Total Pumpage. Gallons.	Pumpage to East of Plainfield. Gallons.	Level of water in wells.
1901.	Jan.	50,914,490	24,983,250	40.50
	Feb.	55,089,870	28,880,250	39.50
	March	57,516,870	29,193,000	41.10
	April	49,179,120	25,124,750	45.65
	May	49,659,230	21,374,250	46.10
	June	64,293,430	27,967,500	45.75
	July	64,298,040	26,919,000	43.50
	Aug.	58,854,880	25,382,250	43.65
	Sept.	57,111,300	24,059,250	44.70
	Oct.	55,731,660	23,329,500	44.05
	Nov.	53,829,280	23,129,250	42.85
	Dec.	57,610,050	24,419,250	42.65
	Totals	674,068,220	304,761,500	
1902.	Jan.	56,956,800	24,766,500	44.40
	Feb.	53,240,400	22,899,750	44.45
	March	62,497,480	26,297,250	48.90
	April	58,852,050	23,994,000	49.10
	May	63,711,140	24,184,500	47.35
	June	65,917,010	25,647,750	45.80
	July	64,161,370	25,065,500	44.40
	Aug.	61,586,420	24,757,300	43.30
	Sept.	58,[illegible]20,140	meter out	42.50
	Oct.	58,024,720	" "	43.60
	Nov.	56,023,17[illegible]	" "	43.80
	Dec.	58,926,240	" "	46.50
	Totals	718,616,940	197,612,550	
1903.	Jan.	64,200,070	meter out	46.85
	Feb.	58,017,716	22,299,000	47.80
	March	61,254,620	24,102,000	49.85
	April	61,518,850	23,874,000	50.75
	May	81,803,130	29,[illegible]99,000	48.20
	June	70,291,650	25,2[illegible]9,000	49.00
	July	77,051,190	26,497,[illegible]00	48.00
	Aug.	73,845,120	25,000,0[illegible]0	48.35
	Sept.	68,695,350	24,992,00[illegible]	48.20
	Oct.	67,332,410	25,000,000	51.20
	Nov.	70,088,820	24,782,000	49.00
	Dec.	77,580,520	31,195,000	47.75
	Totals	831,679.446	282,709,000	
1904.	Jan.	87,865,770	34,769,000	46.85
	Feb.	84,746,020	34,344,000	46.00
	March	89,702,470	35,553,000	46.70
	April	60,331,210	32,604,000	48.05
	May	85,013,950	34,742,000	[illegible]6.60
	June	87,098,090	37,107,000	[illegible].10
	July	95,698,360	41,317,000	4[illegible]5
	Aug.	110,214,000	50,882,000	44[illegible]
	Sept.	91,681,720	39,964,750	47.[illegible]
	Oct.	89,471,950	37,725,000	46.9[illegible]
	Nov.	83,519,400	35,474,750	46.30
	Dec.	88,799,820	37,002,250	44.55
	Totals	1,054,142,750	451,484,750	
1905.	Jan.	90,469,510	39,683,500	44.80
	Feb.	90,353,270	36,909,750	43.80
	March	87,332,990	39,011,500	46.95
	April	79,321,480	35,836,500	47.00
	May	90,338,730	41,000,000	45.00
	June	87,041,640	36,989,500	43.43
	July	109,357,290	49,957,750	41.30
	Aug.	105,498,720	56,768,000	41.10
	Sept.	89,747,010	49,674,250	45.00
	Oct.	90,477,780	44,095,750	43.05
	Nov.	92,283,400	47,629,000	41.90
	Dec.	98,766,790	51,919,250	41.90
	Totals	1,110,988,610	529,474,750	

Year.	Month.	Total Pumpage. Gallons.	Pumpage to East of Plainfield. Gallons.	Level of water in wells.
1906.	Jan.	86,486,400	37,051,000	43.00
	Feb.	85,130,460	35,598,000	41.15
	March	95,992,260	44,294,500	42.85
	April	97,742,540	44,212,000	44.90
	May	104,369,330	48,330,400	44.45
	June	104,503,570	49,921,500	42.85
	July	99,980,640	41,387,450	42.05
	Aug.	117,141,000	60,962,250	40.80
	Sept.	122,914,380	65,803,250	39.80
	Oct.	109,400,370	54,283,750	38.70
	Nov.	106,748,760	52,662,500	38.40
	Dec.	125,785,850	62,821,500	36.30
	Totals	1,258,195,560	597,328,100	
1907.	Jan.	140,465,140	71,321,300	36.20
	Feb.	120,236,180	51,715,250	36.05
	March	123,243,860	56,169,000	37.80
	April	114,151,330	35,314,750	38.45
	May	127,133,500	64,465,000	38.30
	June	119,621,290	53,562,500	37.45
	July	140,648,620	61,345,250	36.05
	Aug.	139,532,030	62,178,250	34.85
	Sept.	123,824,380	54,623,750	34.65
	Oct.	114,270,850	44,193,000	32.65
	Nov.	106,095,850	42,029,750	35.20
	Dec.	110,978,770	48,333,000	36.55
	Totals	1,480,201,800	640,250,800	
1908.	Jan.	114,254,270	45,959,250	38.65
	Feb.	120,059,910	44,894,500	39.70
	March	113,994,550	45,858,000	41.80
	April	110,642,610	45,360,750	41.60
	May	115,308,360	48,834,750	43.35
	June	129,201,360	53,035,500	41.80
	July	139,801,180	58,357,500	40.25
	Aug.	126,786,550	52,643,500	39.35
	Sept.	119,627,990	47,684,750	38.15
	Oct.	120,391,620	47,398,250	37.30
	Nov.	110,502,370	43,914,750	36.00
	Dec.	116,303,350	45,594,700	34.70
	Totals	1,436,874,120	579,536,200	
1909.	Jan.	123,509,230	46,595,750	34.20
	Feb.	109,345,700	42,037,500	34.50
	March	116,626,920	44,453,750	36.30
	April	113,575,080	45,327,000	38.20
	May	122,229,900	48,919,500	38.90
	June	128,936,350	52,249,250	36.90
	July	168,779,340	64,480,000	34.05
	Aug.	144,434,460	56,183,500	33.85
	Sept.	126,015,690	50,835,250	33.10
	Oct.	124,208,000	49,753,250	32.45
	Nov.	117,637,790	49,700,500	31.40
	Dec.	127,236,730	48,805,750	30.40
	Totals	1,522,535,190	599,341,000	
1910.	Jan.	146,185,780	51,737,500	30.10
	Feb.	129,400,460	Meter moved to El Mora.	30.35
	March	130,532,710	Meter moved to El Mora.	32.50
	April	124,785,870	Meter moved to El Mora.	32.75
	May	89,328,900	Pumping from El Mora.	34.50
	June	95,431,500	Pumping from El Mora.	33.80
	July	154,820,870		32.25
	Totals	870,436,090		

TABLE II.

List of Deep Wells in Eastern New Jersey.

Well No. 1, Roselle, N. J.—Elevation of ground 98 feet. 10 feet in earth and balance of depth in red shale. 6-inch well drilled in 1895 for J. H. Chiver. Well 117 feet deep, water struck at depth of 115 feet and rose to within 20 feet of surface. When pumping at rate of 10 gallons per minute water fell in well to near its bottom.

Well No. 2, Goodmans, N. J.—Elevation of ground 60 feet. 6-inch well drilled in 1889 for Lehigh Valley Railroad. 33 feet in earth, balance of depth in red shale. Well 106 feet deep, water struck at 100 feet depth and rose to within 30 feet of surface. Pumping at rate of 20 gallons per minute, draws water down 10 feet in well.

Well No. 3, Union, N. J.—Elevation of ground 120 feet. 6-inch well drilled in 1899 for C. H. Johnson. 23 feet earth and balance in red shale. Well 176 feet deep, water struck at depth of 170 feet, and rose to within 4 feet of surface. Pumping at rate of 10 gallons per minute; draws water down 20 feet in the well.

Well No. 4, Linden, N. J.—Elevation of ground 20 feet. 6-inch well drilled in 1899 for Pennsylvania Railroad. 10 feet of earth, balance in red shale; well 122 feet deep, water struck at depth of 120 feet and rose to within 9 feet of the surface. Pumping at rate of 15 gallons per minute; draws water down 13 feet in the well.

Well No. 5, Aldene, N. J.—Elevation of ground 62 feet. 8-inch well drilled in 1900 for Jackson Architectural Iron Works. 38 feet of soil and balance in red shale. Well 105 feet deep, water struck at depth of 100 feet and rose to 3 feet above surface. Pumping at rate of 100 gallons per minute; draws the water down 27 feet below the top of the well.

Well No. 6, Linden, N. J.—Elevation of ground 35 feet. 6-inch well drilled in 1901 for Maline Wians. 32 feet of soil and balance red shale. Well 100 feet deep, water struck at depth of 90 feet and rose to within 12 feet of the surface. Pumping at rate of 15 gallons per minute the water does not lower in the well.

Well No. 7, New Orange, N. J.—Elevation of ground 100 feet. 8-inch well drilled in 1901 for the American Circular Loom Company. 72 feet of soil, clay and sand and balance red shale. Well 238 feet deep, water struck at depth of 200 feet and rose to within 30 feet of the surface. Pumping at the rate of 50 gallons per minute lowers the water 45 feet in the well.

Well No. 8, New Orange, N. J.—Elevation of ground 100 feet. 8-inch well drilled in 1901 for Monarch Pipe Covering Company; 65 feet of earth, clay and sand and balance in red shale. Well 155 feet deep, water struck at depth of 150 feet, and rose to within 45 feet of the surface. Pumping at the rate of 55 gallons per minute lowers the water 20 feet in the well.

Well No. 9, New Orange, N. J.—Elevation of ground 130 feet. 8-inch well drilled in 1903 for S. H. Kerbaugh; 45 feet of earth, balance in red shale. Well 206 feet deep, water struck at depth of 150 feet and rose to within 9 feet of the surface. Pumping at the rate of 60 gallons per minute lowers the water 5 feet in the well.

Well No. 10, New Orange, N. J.—Elevation of ground 65 feet. 8-inch well drilled in 1906 for James Arthur. 47 feet in earth, clay and sand, balance in red shale. Well 203 feet deep, water struck principally below 200 feet, but in small amounts at different depths below 100 feet, and rises to within 31 feet of the top. Pumping at the rate of 100 gallons per minute lowers the water 5 feet in the well.

Well No. 11, New Orange, N. J.—Elevation of surface 105 feet. 6-in well drilled in 1907 for Upsala College. 170 feet of earth, clay and sand, balance red shale. Well 190 feet deep, water struck at depth of 185 feet and rose to within 40 feet of the surface. Pumping at the rate of 20 gallons per minute lowers the water 20 feet in the well.

Well No. 12, Netherwood, N. J.—Elevation of surface 128 feet. 6-inch well drilled in 1902 for M. J. Geary. 120 feet of earth, boulders and sand, balance red shale. Well 132 feet deep, water struck at 130 feet depth and rose to within 65 feet of the surface. Pumping at the rate of 12 gallons per minute did not lower water in well.

Well No. 13, Netherwood, N. J.—Elevation of ground 126 feet. 6-inch well drilled for Mrs. S. A. Duflon in 1900. 134 feet of earth, sand and boulders, balance red shale. Well 176 feet deep, water struck at 140 feet and rose to within 34 feet of the surface. Pumping at the rate of 40 gallons per minute lowers the water 2 feet in the well.

Well No. 14, Netherwood, N. J.—Elevation of ground 182 feet. 6-in well drilled for Mrs. S. A. Duflon in 1890. Total depth of well drilled in earth, sand and boulders; water on top of the red shale. Well 140 feet deep, water struck at 140 feet and rose to within 100 feet of the surface. Pumping at the rate of 10 gallons per minute did not lower the water in well.

Well No. 15, Netherwood, N. J.—Elevation of ground 182 feet. 6-inch well drilled for Mrs. S. A. Duflon in 1895. 64 feet

of earth, sand and boulders, and the balance in red shale. Well 100 feet deep, water struck at 98 feet and rose to within 45 feet of the surface. Pumping at the rate of 10 gallons per minute did not lower the water in the well.

Well No. 16, Netherwood, N. J.—Elevation of ground 210 feet. 6-inch well drilled for Otto Arens in 1900. 145 feet of earth, sand and boulders, and the balance was in red shale. Well 234 feet deep, water struck from 147 to 224 feet and rose to within 170 feet of the surface. Pumping at the rate of 20 gallons per minute cleared the well so that the water rose after the test to within 139 feet of the surface.

Well No. 17, Netherwood, N. J.—Elevation of ground 205 feet. 6-in well drilled for William S. Darling in 1890. Total depth of well drilled in earth, sand and boulders; this was a dug well 80 feet deep. Well 132 feet deep, water struck at 130 feet and rose to within 100 feet of the surface. Pumping at the rate of 10 gallons per minute did not lower the water in the well.

Well No. 18, Netherwood, N. J.—Elevation of ground 145 feet. 6-inch well drilled for W. L. Brown in 1890. Total depth of well drilled in earth, sand and boulders. Well 100 feet deep, water struck at 98 feet and rose to within 90 feet of the surface. Pumping at the rate of 10 gallons per minute did not lower the water in the well.

Well No. 19, Alton, N. J.—Elevation of ground 120 feet. 6-inch well drilled for Walter Melick in 1904. 95 feet of earth, sand and boulders, balance red shale. Well 170 feet deep, water struck at 160 feet and rose to within 45 feet of the surface. Pumping at the rate of 25 gallons per minute lowers the water 30 feet in the well.

Well No. 20, Elizabethport, N. J.—Elevation of ground 28 feet. 8-inch well drilled for Riker Motor Company in 1901. 56 feet of earth and clay, balance red shale. Well 500 feet deep, no water struck.

Well No. 21, Elizabethport, N. J.—Elevation of ground 28 feet. 8-in well drilled for Riker Motor Company in 1901. 59 feet of earth and clay, balance red shale. Well 150 feet deep, water struck at 100 feet and again at 150 feet and rose to within 80 feet of the surface. Pumping at the rate of 28 gallons per minute and also at 65 gallons per minute the water lowered 20 and 70 feet in the well respectively.

Well No. 22, Elizabethport, N. J.—Elevation of ground 28 feet. 8-inch well drilled for A. & F. Brown in 1901. 50 feet of earth and clay, balance red shale. Well 150 feet deep, water struck at 100 feet and rose to within 60 feet of the surface. Pumping at the rate of 30 gallons per minute and also at 40

gallons per minute the water lowered 40 and 60 feet in the well, respectively.

Well No. 23, Elizabethport, N. J.—Elevation of ground 20 feet. 6-inch well drilled for Herman Jenisch in 1901. 55 feet of earth and clay, balance soft shale. Well 400 feet deep, water struck at 55 feet and again at 398 feet and rose to within 30 feet of the surface. Pumping at the rate of 9 gallons per minute and also at 10 gallons per minute the water lowered 35 feet and 80 feet in the well, respectively.

Well No. 24, Elizabethport, N. J.—Elevation of ground 30 feet. 6-in well drilled for Margaret and William Herbert in 1901. 63 feet of earth and clay, balance soft shale. Well 122 feet deep, water struck at 120 feet and rose to within 26 feet of the surface. Pumping at the rate of 50 gallons per minute did not lower the water in the well.

Well No. 25, Elizabethport, N. J.—Elevation of ground 30 feet. 8-in well drilled for William Herbert in 1899. 58 feet of earth and clay, balance soft shale. Well 216 feet deep, water struck at 125 feet and rose to within 40 feet of the surface. Pumping at the rate of 10 gallons per minute lowers the water 85 feet in the well.

Well No. 26, North Plainfield, N. J.—6-in well drilled for J. P. St. John in 1887. 74 feet of rock. No data as to where water was struck, or as to the yield of the well.

Well No. 27, North Plainfield, N. J.—6-in well drilled for Mr. Waltman in 1887. 95 feet to rock. No data as to where water was struck, or as to the yield of the well.

Well No. 28, North Plainfield, N. J.—6-inch well drilled for J. L. Darby in 1888. 43 feet to rock. No data as to where water was struck, or as to the yield of the well.

Well No. 29, North Plainfield, N. J.—6-inch well drilled for Mr. Stule in 1888. 76 feet to rock. No data as to where water was struck, or as to the yield of the well.

Well No. 30, Ashbrook, N. J.—6-inch well drilled for Lehigh Valley Railroad in 1891. Elevation of ground 60 feet. No rock. Well 51 feet deep. No data as to where water was struck, or as to the yield of the well.

Well No. 31, Fords, N. J.—Elevation of ground 100 feet. 6-inch well drilled for M. D. Valentine in 1890. Soft shale. Well 152 feet deep. No data as to where water was struck, or as to the yield of the well.

Well No. 32, Woodbridge, N. J.—Elevation of ground 30 feet. 6-inch well drilled for M. D. Valentine. 41 feet to rock. Well 104 feet deep. No data given as to where water was struck.

It rose to within 30 feet of the surface. Well pumped at rate of 10 gallons per minute.

Well No. 33, Graceland Improvement Co.—Elevation of ground 180 feet. No data given as to the size of well, which was drilled in 1892. No rock and no report on water. Well was 74 feet deep.

Well No. 34, Martinsville, N. J.—Elevation of ground 290 feet. No data given as to size of well. 40 feet to rock and balance blue and red shale. Well 114 feet deep. Water rose to within 50 feet of surface. No data given as to where water was struck. Well pumped at rate of 15 gallons per minute.

Well No. 35, Cranford, N. J.—Elevation of ground 80 feet. No data given as to the size of the well, which was drilled for N. R. Park. 66 feet to rock. Well 200 feet deep. No data given as to where water was struck. It rose to within 42 feet of the surface. Well pumped at 80 gallons per minute.

Well No. 36, Westfield, N. J.—Elevation of ground 130 feet. No data given as to the size of well, which was drilled for J. T. Tubby in 1901. 93 feet to rock, balance red shale. Well 150 feet deep. No data given as to where water was struck. Well pumped at rate of 10 gallons per minute.

Well No. 37, Westfield, N. J.—Elevation of ground 100 feet. No data given as to the size of well, which was drilled for G. W. Beatty in 1901. 51 feet to rock, balance red shale. Well 101 feet deep. No data given as to where water was struck. It rose to within 22 feet of the surface. Well pumped at rate of 20 gallons per minute.

Well No. 38, Westfield, N. J.—Elevation of ground 130 feet. No data given as to size of well, which was drilled for Elizabeth M. Urban in 1902. 45 feet to rock, balance red shale. Well 105 feet deep. No data given as to where water was struck. It rose to within 34 feet of the surface. Well was pumped at rate of 5 gallons per minute.

Well No. 39, Oak Tree, N. J.—Elevation of ground 100 feet. No data given as to size of well, which was drilled for the Lehigh Valley Railroad Company in 1901. No rock. Well 51 feet deep. No data given as to where water was struck, or as to the yield of the well.

Well No. 40, Piscataway, N. J.—Elevation of ground 80 feet. No data given as to year it was drilled, nor size of well. 63 feet to rock, balance red shale. Well 104 feet deep. No data given as to where water was struck, or as to the yield of the well.

Well No. 41, Linden, N. J.—Elevation of ground 25 feet. No data given as to size of well, which was drilled for the Pennsylvania Railroad in 1899. 40 feet to rock, balance red shale.

Well 122 feet deep. No data given as to where water was struck. It rose to within 22 feet of the surface. Well pumped at rate of 15 gallons per minute.

Well No. 42, Plainfield, N. J.—Elevation of ground 100 feet. 6-inch well drilled for the Spicer Manufacturing Company. No data given as to the year it was drilled. 54 feet to rock, balance red shale. Well 156 feet deep. No data given as to where water was struck. It rose to within 50 feet of the surface. Well pumped at rate of 60 gallons per minute.

Well No. 42-A, South Plainfield, N. J.—Elevation of ground 60 feet. No data given as to size of well; drilled for the Spicer Manufacturing Company in 1910. Top 1 foot of soil, remainder shale. Well 120 feet deep. No data given as to where water was struck, or as to the yield of the well, but good yield reported.

Well No. 43, Plainfield, N. J.—Elevation of ground 85 feet. No data given as to size of two wells drilled for the Plainfield Gas and Electric Light Company. 400 feet in red shale. 15 feet quicksand at surface. 300 gallons per minute for two wells. No data given as to where water was struck.

Well No. 44, South Plainfield, N. J.—Elevation of ground 55 feet. Three 12-inch wells for Middlesex Water Company, near Lehigh Valley Depot 200 feet deep in red shale, each flowing 150 gallons per minute and each producing 500 gallons per minute on pumping. No data given as to where water was struck.

Well No. 45, Metuchen, N. J.—Elevation of ground 115 feet. Seven wells from 40 to 75 feet deep. Drift 18 to 25 feet, balance red shale. No data given where water was struck, or as to the yield of the wells.

Well No. 46, Elizabeth, N. J.—Elevation of ground 60 feet. 35 sand wells about 103 feet deep, all flowing. Total flow said to be 2 million gallons daily. Drilled for the Union Water Company.

Well No. 46-A, Elizabeth, N. J.—Elevation of ground 60 feet. Drilled for the Union Water Company. 10 rock wells about 500 feet deep, all flowing. Total flow said to be 2 million gallons daily. Pumping test, 6 million gallons daily, water lowered from 13 to 28 feet from surface.

Well No. 47, Chatham Water Works.—Elevation of ground 188 feet. One 5-inch well 90 feet deep and three 6-inch wells 90 feet deep. In the 5-inch well the water rose 8.7 above surface and in the other three the water overflowed. Natural flow of one 6-inch is stated at 150 gallons per minute. No change in flow since 1897 when first made.

Well No. 48, Madison Water Works.—Elevation of ground 192 feet. One 8-inch well 83 feet deep, water rose 8 feet above

surface. Overflow 2 feet above surface; 400 gallons per minute. Three wells, 101, 103 and 148 feet deep. Water overflows 1,000,000 gallons daily.

Well No. 49, New Brunswick, N. J.—Elevation of ground 60 feet. Well drilled for Rutgers College. Red shale. 244 feet deep. Pumped at rate of 12 gallons per minute.

Well No. 50, on Canoe Brook.—Elevation of ground 180 feet. Two 8-inch wells, one 90 feet deep and the other 125 feet deep. Clay and tile overlying water-bearing gravel. Water rose 25 feet above surface. 1 million gallons daily estimated flow.

Well No. 51, New Durham, N. J.—Elevation of ground 120 feet. Well drilled for A. B. Osgoodby. Shale. 63 feet deep. No data given as to where water was struck, or as to the yield of the well.

Well No. 52, F. W. Von Hoffe.—Elevation of ground 60 feet. A 4-inch well. Red shale. No data is given as to where water was struck, depth of well or yield of well.

Well No. 53, Stewart Hartshorne.—Elevation of ground 100 feet. 8-inch well 83 feet deep and 6-inch well 307 feet yielded 125 and 175 gallons per minute each.

Well No. 54, Stewart Hartshorne.—Several wells 60 to 100 feet deep. In sand and gravel deposits. Yield collectively 5,000,000 gallons daily. Short Hills and Milburn supplies.

Well No. 55, Hiram Steel.—2-inch well, 33 feet deep in sand and gravel. Water found on top of shale rock.

Well No. 56, East Orange Water Company.—Several wells in sand and gravel.

Well No. 57, Netherwood Supply of Plainfield-Union Water Company.—Original 20 wells, 6-inch diameter, about 70 feet deep in sand and gravel. Yield about 4,000,000 gallons daily.

Well No. 57-A, Netherwood Supply of Plainfield-Union Water Company.—10 wells in shale rock 400 feet deep; plant not yet completed. Yield of some of the wells said to be 425,000 gallons per day.

Well No. 58, Aeolian Company, Cranford, N. J.—Well in shale rock; good yield, but no data available respecting same.

Well No. 59, Tottenville, S. I.—Elevation of ground 15 feet. Well 37 feet for Otto Jaeger in gravel, clay and sand. Yield 10 gallons per minute.

Well No. 60, Tottenville, S. I.—Elevation of ground 15 feet. Well 36 feet for Abram Cole, in gravel, clay and sand. Yield 5 gallons per minute.

Well No. 61, Kresichersville, S. I.—Well 196 feet deep for Albert Killmeyer. No water was found.

Well No. 62, Maurer, N. J.—Elevation of ground 10 feet.

Well 50 feet deep in clay and sand for Smelting Works. Water rises within 3 feet of surface; yields 25,000 gallons per day.

Well No. 63, Maurer, N. J.—For Smelting Works. Elevation of ground 25 feet. Depth 87 feet through blue clay and rock. Yielded no water.

Well No. 64, 2 Miles West of Perth Amboy, N. J.—For Raritan H. & P. B. Company. Depth 52 feet and got water. Elevation of ground 5 feet.

Well No. 65.—45 feet deep in clay and 30 feet from No. 64; yields 30,000 gallons daily. For Raritan H. & P. B. Co. Elevation of ground 5 feet.

Well No. 66.—50 feet deep for Raritan H. & P. B. Co. Yield 20,000 gallons daily; affected by tides. Elevation of ground 5 feet.

Well No. 67, Metuchen, N. J.—Well 53 feet deep in gravel and sand for Marcus Shantz. Elevation of ground 110 feet.

Well No. 68, Fords, N. J.—Well 227 feet deep in gravel, clay and sand for Hans Ericson. 135 feet to red shale. Yields 2 gallons per minute. Elevation of ground 160 feet.

Well No. 69-72, Perth Amboy, N. J.—4 wells for C. Pardee in gravel, sand and clay. Three of the wells, No. 69, No. 70 and No. 72, 146, 116 and 31 feet deep respectively, were dry. Well No. 71, 53 feet deep, gave small amount of water. Elevation of ground 3 feet.

Well No. 73, Maurer, N. J.—For H. Maurer. 78 feet. Through clays and sandstone. Gave small yield at 59 feet. Elevation of ground 20 feet.

Well No. 74, Woodbridge, N. J.—For M. D. Valentine & Brother. 56 feet deep in drift and rock. No data as to yield. Elevation of ground 50 feet.

Well No. 75, Edgar Station.—For S. S. Tucker. 87 feet through drift and red shale. Water secured. Elevation of ground 45 feet

Well No. 76, Edgar Station.—For Ellis Edgar. 76 feet through drift and red shale. Water secured. Elevation of ground 115 feet.

Well No. 78, New Brunswick, N. J.—Well for Natatorium. 135 feet through drift and red shale. Yielded 75 gallons per minute when pumped. Elevation of ground 20 feet.

Well No. 79, Runyon Station, Pennsylvania Railroad.—2-inch well for City of Perth Amboy. 160 feet deep, 159.5 feet in drift. No data as to yield. Elevation of ground 23 feet.

Well No. 80, Bayonne, N. J.—Well for G. W. Gates, 31 feet deep. No data as to yield. Rock at 30 feet. Elevation of ground 23 feet.

Well No. 81, Newark, N. J.—6-inch well for Citizens' Gas Light Company. 35 feet of drift, then 55 feet of red shale, then Belleville white sand to 600 feet depth. Yield 50 gallons per minute. Elevation of ground 30 feet.

Well No. 82, Newark, N. J.—6-inch well for Unger Bros. 300 feet deep. 80 feet to shale. Yield 35 gallons per minute.

Well No. 83, Newark, N. J.—Well for Weingarten Bros. 200 feet deep, all in shale. Yielded 30 gallons per minute. Elevation of ground 50 feet.

Well No. 84, Newark, N. J.—10-inch well for P. Louentrout, 400 feet deep, all in red shale. Good supply.

Well No. 85, Harrison, N. J.—3 wells for B. Atha and Hollingsworth, 80 feet deep in sand and gravel. Yield 85 gallons per minute. Elevation of ground 5 feet.

Well No. 86, Roselle, N. J.—Well for St. Mary's Cemetery, 120 feet deep in red shale. Abundant supply.

Well No. 87, Fort Lee, N. J.—Well for Bergen County Traction Company, in red shale under trap rock. 30 gallons per minute. Yielded at depth of 150 feet.

Well No. 88, Jersey City, N. J.—For Colgate Co. 35 feet of drift to shale. Well 1500 feet deep. Yield 15 gallons per minute.

Well No. 89, Jersey City, N. J.—Well 90 feet deep in fine sand for J. C. Paper Co.; gives good supply.

Well No. 90, Passaic, N. J.—12-inch well for Reid & Barry. Sand and gravel for 80 feet, then red shale. Well 300 feet deep and yields 500 gallons per minute.

Well No. 91, Bayonne, N. J.—6-in well in red shale for Bayonne Chemical Co. Good water struck. No data as to depth, or yield. Elevation of ground 20 feet.

Well No. 92, Lake Hopatcong, N. J.—Well for H. W. Cortrights, 100 feet deep, 6 feet of earth, then granite to 100 feet. Yield 2 gallons per minute. Elevation of ground 360 feet.

Well No. 93, Morristown, N. J.—Well for L. C. Gillespie, 204 feet deep in hard granite. No data as to yield.

Well No. 94, Ridgewood, N. J.—Well for James Wharton, 83 feet deep in sand. Water rises to within 30 feet of surface. Yield is 10 gallons per minute.

Well No. 95, at Passaic, N. J.—Well for W. H. Anglemans, 84 feet deep. 64 feet of drift on shale. Yield 20 gallons per minute.

Well No. 96, Passaic, N. J.—Well for Henry Rodel. 100 feet deep. 90 feet in drift, balance in red shale. Yield 25 gallons per minute.

Well No. 97, Passaic, N. J.—For D. J. Dow. Depth 70 feet, 38 feet drift, balance red shale. No data as to yield.

Well No. 98, Passaic, N. J.—For Botany Mills. Depth 100 feet, 93 feet being in drift. No data as to yield.

Well No. 99, Passaic, N. J.—For the Passaic Beef Co. Well 171 feet deep in red sandstone. Water rises to within 17 feet of surface. Yield of well 25 gallons per minute.

Well No. 100, Passaic, N. J.—For Richard Kipp. Well 101 feet deep, 51 feet drift and balance red shale. Water rises to within 10 feet of surface. Yield of well 25 gallons per minute.

Well No. 101, Passaic, N. J.—3 wells northeast of town, 60 feet deep. 20 feet earth, then shale. Good yield, but no data.

Well No. 102, Passaic, N. J.—For Electric Light Co. 20 feet of earth and balance to 125 feet in shale. Yield 375 gallons per minute, water rising to within 25 feet of surface.

Well No. 103, Passaic, N. J.—For Botany Mills. Depth 200 feet. 100 feet in earth. Yield 3 gallons per minute.

Well No. 104, Passaic, N. J.—For John Day. Depth 55 feet Yield 5 gallons per minute. 12 feet through earth to red shale.

Well No. 105, at Arlington.—For A. W. Schuler. Depth 52 feet, 42 feet being through drift. Yield 10 gallons per minute.

Well No. 106, Plainfield, N. J.—Depth 100 feet, 65 feet in drift, balance red shale. Yield 15 gallons per minute.

Well No. 107, Flemington, N. J.—For E. W. Barnes. Depth 120 feet. Yield 20 gallons per minute.

Well No. 108, Flemington, N. J.—For Electric Light Company. Depth 158 feet. 4 feet through earth, balance red shale. Yield 25 gallons per minute.

Well No. 109, Flemington, N. J.—For H. W. Deats. Depth 146 feet. 26 feet of drift to red shale. Yield 40 gallons per minute.

Well No. 110, Flemington, N. J.—For Toran & Abendroth. Well 129 feet deep. 10 feet in clay. balance red shale. Yield of well 30 gallons per minute.

Well No. 111, Port Reading N. J.—For Thomas Brown. Elevation of ground 15 feet. Well 96 feet deep. 35 feet of clay and gravel, balance red shale. Yield 25 gallons per minute.

Well No. 112, Woodbridge, N. J.—For Ellis Mundy. Elevation of ground 25 feet. Well 48 feet deep in sand. No data as to yield of well.

Well No. 113, Keasby, N. J.—For Therbelson & Brown. Elevation of ground 5 feet. Well 84 feet deep in drift and white sand. No data as to yield.

Well No. 114, Perth Amboy, N. J.—For Farrington & Runyon. Elevation of surface 30 feet. Well 96 feet deep in drift and gravel. Yield of well not stated.

Well No. 115, 2½ Miles Northwest of New Brunswick, N. J.—For S. G. Williams. Well 60 feet deep, in red shale. Plenty of water. No data as to amount.

Well No. 116, Fords, N. J.—For William F. Custer. Elevation of ground 145 feet. 156 feet of drift, balance in shale. Well 214 feet deep. Moderate yield.

Well No. 117, Fords, N. J.—For D. La Farge. Elevation of surface 110 feet. Well 98 feet deep, 83 feet being in drift and balance in shale. Water struck at 88 feet below surface and rose 50 feet in the well.

Well No. 118, Carteret, N. J.—For the Car Factory. Elevation of surface 25 feet. 4-inch well 60 feet deep, in sand and clay. No data as to yield. Trap rock 60 feet deep, down from surface.

Well No. 119, Metuchen, N. J.—For Charles Corbin. Well 161 feet deep, 70 feet of shale. No data as to yield.

Well No. 120, Newark, N. J.—For P. Ballantine. 12-inch well, 529 feet deep. 30 feet of drift, balance red shale. Yield 150 gallons per minute.

Well No. 121, Newark, N. J.—For Ziegel, Eisman & Co. Well 326 feet deep, 75 feet drift, balance red shale; good yield, quantity not stated.

Well No. 122, Arlington, N. J.—For Arlington Manufacturing Co. 10-inch well 270 feet deep. 30 feet drift, balance red shale. Yield 375 gallons per minute.

Well No. 123, Soho, N. J.—For C. Northrop. Depth 120 feet. 18 feet drift, balance red shale. Good yield.

Well No. 124, Jersey City, N. J.—For Con. Trac. Co. Depth 1400 feet. 150 feet drift, balance red shale. No data as to yield.

Well No. 125, New Brunswick, N. J.—For Mr. B. Zimmerman. 6-inch well 146 feet deep. 16 feet of drift, balance red shale. Yield not stated.

Well No. 126, Woodbridge, N. J.—For M. D. Valentine & Co. Well 56 feet deep in sand and gravel. Yield not stated.

Well No. 127, Valentine Station of Lehigh Valley Railroad.—Elevation of surface 100 feet. 4-inch well 140 feet deep, 78 feet in sand, balance red shale. Yield not stated.

Well No. 128, Passaic, N. J.—For Lyman Cisco. 21 feet of gravel, balance red shale. Well 111 feet deep. Yield 10 gallons per minute. Water stands 29 feet from top of well.

Well No. 129, Passaic, N. J.—For S. N. De Fries. Well 75

feet deep. 26 feet in drift, balance red shale. Yield 10 gallons per minute, water stands at 24 feet and drops seven (7) feet lower when pumped at 10 gallons per minute rate.

Well No. 130, Afton, N. J.—For Mrs. D. D. Jennings. Well 67 feet deep in sand and gravel. Pumping well at 10 gallons per minute, water stands 43 feet from top.

Well No. 131, Basking Ridge, N. J.—For B. A. Beal. Depth 77 feet in red shale. Yield 2 gallons per minute.

Well No. 132, Basking Ridge, N. J.—For I. H. Tunis. Depth 81 feet in red shale. Yield 2 gallons per minute.

Well No. 133, Millington, N. J.—For W. W. Arnfield. Depth 91 feet, 25 feet earth and balance red shale. Yield 8 gallons per minute. Elevation of surface 270 feet. Water at 53 feet from surface.

Well No. 134, Bayway, N. J.—For J. Stevenson Car Co. 8-inch well. 250 feet deep in red shale. Yield 60 gallons per minute. Water at 23 feet from surface.

Well No. 135, Bayway, N. J.—Stevenson Car Co. 8-inch well, 300 feet deep in red shale; yield 95 gallons per minute. Water at 28 feet from surface.

Well No. 136, Bound Brook, N. J.—For Middle Brook Heights Association. Well 117 feet deep, 15 feet in earth, balance red shale. Yield 60 gallons per minute. Elevation of surface 180 feet. Water at 63 feet from surface.

Well No. 137, Neshanic Station, N. J.—For Miss D. Beitler. Well 85 feet deep, 12 feet in earth, balance in red shale. Yield 15 gallons per minute. Water at 16 feet from surface, which is 110 feet above tide.

Well No. 138, Three Bridges, N. J.—For J. A. Van Fleet. Well 74 feet deep, 14 feet in earth, balance red shale. Yield 10 gallons per minute.

Well No. 139, Flemington, N. J.—For E. W. Barnes. Well 103 feet deep, 4 feet in earth, balance red shale. Yield 10 gallons per minute. 3 feet from surface.

Well No. 140, Flemington, N. J.—For H. E. Dats. Well 96 feet deep, 12 feet in earth, balance red shale. Yield 30 gallons per minute.

Well No. 141, Dover, N. J.—For S. T. Smith. Well 135 feet in drift. Water stands at 60 feet. No data as to yield. Elevation of surface 630 feet.

Well No. 142, Dover, N. J.—For Stove Works. 6-inch well 60 feet deep in drift, flowing well. No data as to yield.

Well No. 143, Dover, N. J.—For D. L. & W. Paint Shop. 6-inch well 214 feet deep. Water flows at surface. No data as to quantity.

Well No. 144, Dover, N. J.—For D. L. & W. R. R. 6-inch well 224 feet deep. Flowing well. No data as to yield.

Well No. 145, Dover, N. J.—For City of Dover. Depth 200 feet. No water secured.

Well No. 146, Mt. Arlington, N. J.—Well 267 feet deep in sand and shale. Water rose within 60 feet of top. No data as to yield.

Well No. 147, Rutherford, N. J.—For Zahn & Bowly. 8-inch well 202 feet deep. 35 feet of drift, balance sandstone. Flowing well, no data as to yield. Elevation of surface 60 feet.

Well No. 148, Perth Amboy, N. J.—For N. Y. Val. Works. 2-inch well 135 feet deep in drift. Water rises to surface. No data as to yield. Elevation of surface 5 feet.

Well No. 149, Keasby, N. J.—For Nat. Nelson Br. Works. Well 89 feet deep in clay and sand. Water in sand. No data as to yield. Elevation of surface 40 feet.

Well No. 150, Keasby, N. J.—For Standard Fire Proofing Co. Depth 72 feet. Elevation of surface 10 feet. Sand and clay for 60 feet. Yield 35 gallons per minute.

Well No. 151, Bonhamton, N. J.—Well 52 feet deep in sand and clay. Water struck, but no data as to yield.

Well No. 152, Bonhamton, N. J.—For N. B. Trac. Co. 6-inch well 208 feet deep. 65 feet in gravel, balance red shale. Water in shale. No data as to yield.

Wells No. 153 and 154, Brunswick Driving Park.—Two wells, 61 and 65 feet deep in red shale. Good yield, but quantity not stated. Elevation of surface 60 feet.

Well No. 156, Middlebush, N. J.—For J. H. Nugent. 6-inch well 112 feet deep in red shale. Plenty of water.

Well No. 157, Middlebush, N. J.—For J. H. Nugent. 6-inch well 150 feet deep. Abundance of water. Elevation of surface 110 feet.

Well No. 158, Middlebush, N. J.—For Bradley. 6-inch well 100 feet deep. Abundance of water.

Well No. 159, Demarest, N. J.—For Mr. Mason. 4-inch well 62 feet deep in red shale. Elevation of surface 90 feet. Good supply of water.

Well No. 160, Metuchen, N. J.—For C. Carter Bell R. Co. 6-inch well 67 feet deep. 30 feet in sand, balance in red shale. Yield not good.

Well No. 161, Highbridge, N. J.—For C. B. Fraleigh. Well 83 feet deep, 21 feet in earth, balance in limestone. Yield 7 gallons per minute.

Well No. 162, Passaic, N. J.—For Botany Mills. Depth 402

feet. Drift 90 feet, balance red shale; water rose to 97 feet of surface. Yield is 200 gallons per minute.

Well No. 163, Passaic, N J.—For Dr. A. C. Pedrick. Well 61 feet deep, 32 feet drift, balance red shale. Yield 10 gallons per minute; water 18 feet from top.

Well No. 164, Passaic, N. J.—For J. P. Lange. Well 100 feet deep, 42 feet earth, balance red shale. Yield 12 gallons per minute; at 46 feet from top.

Well No. 165, Garfield, N. J.—For Cline Co. Well 73 feet deep, 52 feet in sand, balance red shale. Yield 10 gallons per minute at 42 feet from surface.

Well No. 166, South Orange, N. J.—Depth 105 feet in red shale. Yield 10 gallons per minute at 30 feet from top. Elevation of surface 150 feet.

Well No. 167, Lyons Farms, N. J.—Depth 115 feet in sand. Yield 5 gallons per minute. Elevation of surface 60 feet.

Well No. 168, Bernardsville, N. J.—For Mrs. E. L. Joline. Well 122 feet deep, 29 feet drift, balance granite. Yield 5 gallons per minute.

Well No. 169, Hillsboro, N. J.—For A. H. Boun. Elevation of surface 100 feet; 6-inch well 116 feet deep, 33 feet earth, balance red shale. Yield 10 gallons per minute.

Well No. 170, Flemington, N. J.—For Davis Hanson. Well 50 feet deep. 29 feet in earth, balance in red shale. Yield 3 gallons per minute.

Well No. 171, Flemington, N. J.—For L. B. Hoffman. Well 125 feet deep, 10 feet in earth, balance red shale. Yield 35 gallons per minute.

Well No. 172, Communipaw, N. J.—For G. V. Bartlett and Company. Well 500 feet deep produced salt water.

Well No. 173, Belleville, N. J.—For J. Frank Post. Well 150 feet deep in red shale. Yield 150 gallons per minute.

Well No. 174, Waverly, N. J.—For Weston El. Inst. Co. Well 450 feet deep, produced only moderate supply.

Well No. 175, Summit, N. J.—For S. & M. Ice Co. Well 325 feet deep, 60 feet in earth, balance in red shale. Yield 100 gallons per minute.

Well No. 176, Arlington, N. J.—For Sta. Flint Paper Co. Depth 235 feet in shale. Yields good supply, but moderate as to quantity.

Well No. 177, Elizabeth, N. J.—For Clause Bottling Co. Well 275 feet deep in red shale. Good supply.

Well No. 178. Newark. N. J.—For A. F. Bannister & Co. Well 120 feet deep; 20 feet in drift, balance red shale. Yield 52 gallons per minute.

Well No. 179, Newark, N. J.—For C. N. Russell. Well 180 feet deep, 10 feet drift, balance red shale. Yield 25 gallons per minute.

Well No. 180, Newark, N. J.—For Feigenspan Brewing Co. 10-inch well 350 feet deep, 100 feet in drift, balance in shale. Yield 200 gallons per minute.

Well No. 181, Newark, N. J.—For Wheeler Russell Hat Co. Well 250 feet deep in clay and sand. Yield 75 gallons per minute.

Well No. 182, Newark, N. J.—For McAndrews & Forbes. Well 220 feet deep, 20 feet in earth, balance in shale. Yield 100 gallons per minute.

Well No. 183, Kearny, N. J.—Home for Disabled Soldiers. Well 600 feet deep, 10 feet in drift, balance in shale. Yield 50 gallons per minute.

Well No. 184, Harrison, N. J.—For Hahn & Stumpf. Well 350 feet deep, 100 feet in drift, balance in shale. Yield 50 gallons per minute.

Well No. 185, Waverly, N. J.—For Ricketts & Banks. Well 280 feet deep, 80 feet drift, balance shale. Yield 40 gallons per minute. Elevation of surface 20 feet.

Well No. 186, Sewaren, N. J.—For Port Reading R. R. Well 200 feet deep, 50 feet drift, balance shale. Yield 25 gallons per minute. Elevation of surface 10 feet.

Well No. 187, Bernardsville, N. J.—For Miss M. Appleton. Well 128 feet deep, 39 feet earth, balance granite. Yield 35 gallons per minute.

Well No. 188—For S. F. Condict. Well 224 feet deep in granite. Yield 7 gallons per minute.

Well No. 189, Bernardsville, N. J.—For Geo. B. Post. Well 600 feet deep, 20 feet in earth, balance granite. Yield 80 gallons per minute.

Well No. 190, Bernardsville, N. J.—For Mrs. Bradley. 6-inch well 180 feet deep, 15 feet in earth, balance granite. Yield 100 gallons per minute. Water rose to within 20 feet of surface.

Well No. 191, Flemington, N. J.—For G. C. Pedrick. Well 51 feet deep, 15 feet in earth, balance in red shale. Yield 18 gallons per minute.

Well No. 192, Flemington, N. J.—For Flemington Water Co. Well 407 feet deep. Mixed strata. Water from shale; yield with water at 161 feet, 107 gallons per minute. Elevation of surface 140 feet.

Well No. 193, Readington, N. J.—For J. E. Hoagland. Well 87 feet deep, 20 feet earth, balance red shale. Yield 15 gallons per minute. Elevation of surface 50 feet.

Well No. 194, Three Bridges, N. J.—For Farmers' Dispatch Co. Well 94 feet deep, 30 feet earth, balance red shale. Yield 15 gallons per minute.

Well No. 195, Liberty Corner, N. J.—For F. Ballentine. Well 109 feet deep in red shale. Yield 7 gallons per minute. Elevation of surface 265 feet.

Well No. 196, Somerville, N. J.—For Children's Home. 6-inch well 152 feet deep, 51 feet of drift, balance red shale. Yield 25 gallons per minute.

Well No. 197, Union, N. J.—For C. H. Johnson. Well 176 feet deep. 23 feet in earth, balance in shale. Elevation of surface 115 feet. Yield with water at 60 feet, 10 gallons per minute.

Well No. 198, Elizabeth, N. J.—For Wm. Weilich. Well 216 feet deep, 58 feet of drift, balance in shale. Yield 10 gallons per minute.

Well No. 199, Summit, Near Passaic River.—Well 120 feet deep in drift, gravel and red shale. Well flowed, but abandoned; water poor.

Well No. 200, Newark, N. J.—For Celluloid Manufacturing Co. 10-inch well 827 feet deep. 100 feet of drift, balance red shale. Yield 200 gallons per minute.

Well No. 201, Newark, N. J.—For Conley, Clark & Co. Well 400 feet deep, 225 feet in drift, balance in shale. Poor yield.

Well No. 202, Kearney, N. J.—For Linoleum Works. 12-inch well 355 feet deep, 35 feet in drift, balance red shale. Yield 150 gallons per minute.

Well No. 203, West Orange, N. J.—For E. V. Connett. 8-inch well 384 feet deep, 50 feet in earth, balance in shale. Yield 100 gallons per minute. Elevation of surface 180 feet.

Well No. 204, Avon Park, N. J.—For C. L. Wright. 4-inch well 210 feet deep, 160 feet in drift, balance in red shale. Water stands at 130 feet from top. Elevation of surface 150 feet.

Well No. 205, Two Bridges, N. J.—For M. Terry. 4-inch well 98 feet deep. 78 feet in drift, balance in shale. Water stands 20 feet from top.

Well No. 206, Mt. Pleasant, N. J.—4-inch well 116 feet deep, 90 feet in sand and gravel, balance in red shale. No data as to yield.

Well No. 207, Three Miles West of New Brunswick, N. J.—For S. G. Williams 4-inch well 58 feet deep, in red shale Large supply.

Well No. 208, One Mile West of New Brunswick, N. J.—

For Dist. Tel. Co. 4-inch well 58 feet deep in red shale. Good supply.

Well No. 209, Lake Hopatcong, N. J.—6-inch well 75 feet deep in granite. Yield 5 gallons per minute.

Well No. 210, Bernardsville, N. J.—For C. M. Chapin. 6-inch well 380 feet deep, 51 feet in earth, balance in granite. Yield 10 gallons per minute.

Well No. 211, Bernardsville, N. J.—For Geo. B. Post. 6-inch well 621 feet deep, 26 feet earth, balance in granite. Yield 8 gallons per minute.

Well No. 212, Elizabeth, N. J.—For Wm. Krause. Well 242 feet deep, 66 feet in earth, balance red shale. Yield 15 gallons per minute. Elevation of surface 30 feet.

Well No. 213, Carteret, N. J.—For Carteret Manufacturing Co. 8-inch well 140 feet deep. 65 feet in clay, balance red shale. Yield 100 gallons per minute.

Well No. 214, Flemington, N. J.—For J. H. Hill. 8-inch well 60 feet deep. 12 feet in clay, balance red shale. Yield 17 gallons per minute.

Well No. 215, Plainfield, N. J.—For Mrs. S. A. Duflon. 6-inch well 176 feet deep. 134 feet of drift. Yield 40 gallons per minute.

Well No. 216, Neshamie, N. J.—For Farmers' Dairy Dispatch Co. Well 115 feet deep in red shale. Yield 15 gallons per minute.

Well No. 217, East Rutherford, N. J.—For Hazleton Bolton Co. 6-inch well 189 feet deep. 48 feet in drift, balance red shale. Yield 70 gallons per minute.

Well No. 218, Milburn, N. J.—For Diam. Paper Co. 8-inch well 300 feet deep. 30 feet in clay, 200 feet in trap and 50 feet in white sandstone. Yield 100 gallons per minute. Elevation of surface 130 feet.

Well No. 219, Irvington, N. J.—For D. C. Meeker. 6-inch well 180 feet deep. 30 feet in drift, balance shale. Yield 150 gallons per minute. Elevation of surface 170 feet.

Well No. 220, Newark, N. J.—For Fagin Bros. 6-inch well 150 feet deep; 20 feet in drift, balance in shale. Yield 100 gallons per minute.

Well No. 221, Newark, N. J.—For McKone Bros. 6-inch well 120 feet deep. 20 feet in drift, balance in red shale. Yield 85 gallons per minute.

Well No. 222, Newark, N. J.—E. E. Hogan Shoe Manufacturing Co. 8-inch well 301 feet deep. 30 feet of drift, balance black sandstone. Yield 125 gallons per minute.

Well No. 223, Oak Tree, N. J.—For Wm. Morrison. 4-inch

well 97 feet deep, 30 feet in clay, balance red shale. Elevation of surface 130 feet.

Well No. 224, Between Plainfield and Dog Corners, N. J.—For J. B. D. Saybocker. 6-inch well 205 feet deep. 149 feet in gravel, sand and clay, balance in red shale. Plenty of water in shale. Elevation of surface 100 feet.

Well No. 225, Waverly, N. J.—For George Sturgel. 6-inch well. 277 feet deep, 60 feet in drift and balance in red shale. Yield 80 gallons per minute. Surface of ground at elevation 10 feet.

Well No. 226, Elizabeth, N. J.—For Am. S. Laundry. 8-inch well 172 feet deep, 32 feet in drift, balance in red shale. Yield 100 gallons per minute.

Well No. 227, Elizabeth, N. J.—For L. F. & H. Hirsch. 8-inch well 168 feet deep in red shale. Yield 45 gallons per minute.

Well No. 228, Elizabeth, N. J.—For United States Co. 8-inch well 317 feet deep, 26 feet in drift, balance in red shale. Yield 160 gallons per minute.

Well No. 229, Elizabethport, N. J.—For H. Jentsch. 6-inch well 400 feet deep, 35 feet in earth, balance in red shale. Yield 10 gallons per minute. Elevation of ground 125 feet.

Well No. 230, Tranquility. N. J.—For Sugar Loaf Dairy Co. 6-inch well 34 feet deep in gravel. Yield 30 gallons per minute.

Well No. 231, Paramus, N. J.—Well 82 feet deep, flowed at surface. In sandstone.

Well No. 232, Saddle River, N. J.—For Mr. Craig. Well 213 feet deep in sandstone. Yield 21 gallons per minute.

Well No. 233, Westwood, N. J.—For Water Works. Well 147 feet deep in sandstone. Yield 147 gallons per minute.

Well No. 234, Allamuchy, N. J.—For W. K. Vanderbilt. 6-inch well in granite. 155 feet deep. Yield 14 gallons per minute.

Well No. 235, Linden, N. J.—For C. H. & J. Winans. 6-inch well 200 feet deep, 16 feet of drift, balance red shale. Yield 690 gallons per minute in 3 weeks' test. Elevation of ground 30 feet.

Well No. 236, Rahway, N. J.—For Mr. Englehardt. 6-inch well 150 feet deep; 30 feet of drift, balance red shale. Plenty of water at 30 feet. Elevation of ground 40 feet.

Well No. 237, Rahway, N. J.—For Edward Savage. 6-inch well 169 feet. deep. 35 feet drift, balance red shale. Yield 8 gallons per minute. Elevation of ground 20 feet.

Well No. 238, Perth Amboy, N. J.—For Barber Asphalt Co. Depth 64 feet, yield 30 gallons per minute.

Well No. 239, Perth Amboy, N. J.—For Barber Asphalt Co. Depth 50 feet; yield 50 gallons per minute.

Well No. 240, Red Bank, N. J.—For D. C. Bruster. 4-inch well 180 feet deep in sand and gravel. Yield 80 gallons per minute, water rises to within 3 feet of surface.

Well No. 241, Rahway, N. J.—For J. Bidens. Well 67 feet deep, 37 feet drift, balance shale. Yield 21 gallons per minute.

Well No. 242, Rutherford, N. J.—For Hazleton Bolton Co. 6-inch well 189 feet deep; 47 feet of drift, balance red shale. Yield 48 gallons per minute.

Well No. 243, Lodi, N. J.—For Town of Lodi. 12-inch well 300 feet deep. 60 feet of drift, balance in red shale. Yield 240 gallons per minute, drawing well down 60 feet.

TABLE III.

RAINFALL TABLES.

Rainfall at Somerville, N. J.

	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907
Jan.	5.93	....	5.54	....	....	4.10	3.75	2.09	3.48	1.46	3.03	4.35	5.08	4.23	2.38	....	4.09	3.78	4.65	....	3.94
Feb.	5.42	4.11	3.17	....	....	1.24	6.17	4.32	1.03	6.74	3.04	3.16	5.53	5.43	0.90	5.77	4.77	2.81	1.79	2.33	2.68
Mar.	4.41	6.87	2.84	....	....	3.99	3.30	2.08	3.19	5.95	2.75	3.23	7.85	3.02	5.42	4.49	4.42	3.82	3.96	3.96	2.72
Apr.	2.67	4.31	5.14	....	....	2.07	5.38	3.02	4.46	1.19	3.92	4.41	1.94	2.66	7.60	3.73	4.01	3.36	2.57	4.34	3.22
May	1.45	4.30	....	....	2.92	4.43	3.96	8.66	3.22	3.83	7.84	7.61	2.43	7.13	5.46	1.84	1.28	2.38	0.42	5.01	4.53
June	5.75	3.30	....	....	1.88	....	4.26	2.66	3.36	6.76	2.80	2.14	2.81	2.85	1.14	5.33	11.66	2.49	....	4.57	3.57
July	9.83	2.77	....	....	4.01	5.44	3.34	1.08	4.67	7.09	11.08	6.57	4.71	5.18	6.15	5.52	5.80	5.53	....	5.98	4.33
Aug.	4.01	6.91	....	....	5.70	3.81	8.32	2.31	2.91	2.51	3.96	5.69	3.25	3.55	7.40	8.30	5.15	8.81	....	4.12	2.79
Sept.	3.30	7.65	....	....	2.22	3.78	3.19	7.15	0.70	4.67	2.03	2.13	7.18	3.18	2.18	5.72	4.93	5.37	6.97	2.33	7.88
Oct.	2.35	4.01	....	....	2.95	0.04	4.68	4.66	3.89	1.56	0.95	4.96	1.52	2.86	1.73	6.71	6.96	4.84	3.24	4.94	4.27
Nov.	2.30	3.10	....	....	2.26	6.74	3.22	3.17	3.32	3.26	4.98	7.52	2.38	3.50	2.12	1.41	1.17	....	....	1.65	5.94
Dec.	5.89	4.14	....	....	4.76	1.51	3.24	3.75	2.37	1.02	5.24	3.52	2.26	2.18	7.75	7.71	4.06	2.06	....	4.26	4.75
Total	53.31						52.81	44.95	36.60	46.04	51.62	55.29	46.94	45.77	50.23	....	58.30	....	....	....	50.62

Rainfall at South Orange, N. J.

	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907
Jan.	3.50	6.35	7.15	2.91	10.55	6.70	4.07	2.11	5.63	1.45	3.62	4.32	4.99	4.26	1.95	....	4.58	2.97	4.24	....	3.24
Feb.	5.07	4.12	2.49	5.32	4.88	1.58	8.90	5.23	1.30	7.85	2.57	3.86	5.68	6.40	0.78	5.69	5.35	3.05	2.15	2.16	2.86
Mar.	2.45	8.20	3.88	6.71	4.81	4.15	3.42	1.73	2.60	4.58	2.56	3.95	6.97	3.50	3.92	4.52	4.51	3.39	4.09	3.70	3.39
Apr.	2.28	4.10	7.54	2.43	3.80	2.73	6.81	2.32	4.35	1.47	2.47	4.61	1.88	2.78	7.34	3.45	3.67	3.81	2.51	5.29	3.80
May	0.93	6.46	3.25	4.62	3.54	4.89	3.37	4.20	2.99	2.21	6.69	6.40	1.62	5.12	6.12	1.91	0.52	3.11	1.21	4.22	5.02
June	5.50	3.62	3.54	5.06	1.78	5.92	3.61	1.70	4.25	5.85	3.20	2.43	1.03	2.88	1.34	6.08	9.28	2.24	....	4.07	3.67
July	9.38	2.62	18.58	5.74	6.00	2.73	1.78	1.10	5.03	7.93	15.80	5.26	3.70	5.72	5.68	4.71	4.22	5.38	....	4.62	1.30
Aug.	6.38	8.33	4.69	4.43	5.51	4.53	7.16	1.48	4.54	1.81	3.43	3.51	5.04	2.78	12.80	2.91	13.57	7.71	....	3.90	2.46
Sept.	1.80	7.93	12.39	4.33	2.76	3.24	2.72	8.10	0.97	4.90	1.51	1.11	6.99	3.82	1.91	6.20	3.80	5.14	6.68	4.22	8.92
Oct.	1.90	5.86	3.46	6.98	2.95	0.77	5.30	5.28	3.61	1.50	1.11	6.39	2.45	5.09	2.08	6.97	11.46	4.27	3.07	4.52	5.29
Nov.	1.60	4.85	11.37	0.78	2.86	7.62	4.05	3.78	3.55	3.03	4.62	7.39	2.60	3.68	1.18	1.24	1.06	....	....	1.06	5.18
Dec.	5.55	4.95	2.47	4.08	4.70	1.63	3.47	4.98	2.66	1.83	4.70	3.39	2.30	2.16	7.57	7.46	4.35	2.55	....	4.74	4.77
Total	46.34	67.39	80.81	53.39	54.14	46.49	54.66	42.01	41.48	44.41	52.28	52.62	45.25	48.19	52.67	....	66.37	....	....	....	49.90

Rainfall at New Brunswick, N. J.

	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907
Jan.	4.74	4.96	6.86	2.59	6.03	5.57	2.53	2.22	5.20	1.61	2.41	4.47	5.26	4.63	2.52	....	4.15	3.98	3.75	....	3.97
Feb.	6.15	3.63	2.35	4.52	4.67	1.81	5.73	3.86	0.95	6.01	3.11	3.72	5.51	5.65	0.98	6.92	4.88	3.09	2.79	2.12	2.35
Mar.	3.59	5.86	3.00	7.39	4.89	4.65	3.22	1.74	3.21	5.84	2.76	3.22	6.82	3.75	5.37	4.83	4.82	3.74	3.93	6.77	4.15
Apr.	3.31	3.89	4.83	2.35	1.65	2.58	4.89	2.87	4.59	1.66	3.48	4.54	1.58	2.59	7.76	3.09	4.53	3.48	3.02	....	2.55
May	1.14	4.89	3.34	3.93	2.91	4.58	3.60	6.23	2.72	3.98	7.16	8.23	2.27	5.51	5.02	1.70	0.46	2.83	1.49	....	4.30
June	6.28	3.43	3.64	3.97	1.95	3.12	3.05	2.28	3.03	4.88	2.31	1.24	3.62	2.89	0.85	6.35	8.13	2.51	....	4.37	3.70
July	6.20	3.42	10.35	7.20	3.25	3.10	2.02	2.43	4.24	4.69	13.14	5.42	6.54	7.18	8.33	5.92	5.63	7.10	....	6.05	4.58
Aug.	7.34	5.55	5.16	5.55	6.88	3.38	9.91	1.87	4.40	2.30	4.23	6.52	4.39	2.39	9.49	5.51	6.52	12.87	....	3.33	1.79
Sept.	3.07	7.80	8.63	5.26	2.20	1.75	3.16	11.03	1.34	4.43	2.10	1.53	8.92	3.77	2.28	5.75	3.23	5.35	4.06	3.05	6.64
Oct.	2.44	5.62	3.32	8.34	3.05	0.55	4.15	4.87	3.69	1.68	1.61	5.83	3.56	4.11	1.69	7.80	7.76	5.21	3.01	3.08	4.85
Nov.	2.30	4.37	8.37	0.93	2.07	6.59	3.93	3.35	3.93	3.32	4.81	7.69	4.32	4.22	2.16	1.66	1.29	....	....	1.62	6.00
Dec.	5.28	3.84	1.95	4.21	4.22	1.67	3.12	4.61	2.64	1.66	5.27	3.54	2.09	2.23	7.85	7.76	4.24	2.93	....	4.25	5.00
Total	51.84	57.26	61.80	56.24	43.77	39.35	49.31	47.31	39.94	42.06	52.39	55.95	54.88	48.92	54.80	.....	55.64	.....	.....	.....	49.88

Rainfall at Plainfield, N. J.

	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907
Jan.	....	....	8.37	....	....	6.86	2.88	2.44	5.02	1.68	2.70	4.90	5.29	4.25	1.95	3.20	4.05	3.99	4.23	2.80	3.57
Feb.	....	....	2.84	....	....	1.60	6.37	4.62	0.98	7.15	3.13	3.88	5.79	6.05	0.79	7.65	4.96	2.79	2.54	2.37	2.81
Mar.	....	....	3.75	....	....	5.36	8.53	2.54	3.15	6.30	2.91	3.66	7.23	4.08	5.20	4.66	4.08	3.87	3.73	5.07	3.17
Apr.	....	....	7.25	....	....	5.00	5.91	3.18	4.31	1.28	3.91	4.82	1.63	3.03	8.22	3.87	4.05	3.27	3.00	4.52	3.10
May	....	....	4.11	....	....	4.95	4.49	5.63	2.76	3.18	6.56	8.54	2.21	5.81	5.16	1.47	0.84	2.12	0.98	5.51	4.00
June	....	....	3.78	....	....	4.63	2.58	5.90	3.53	6.91	2.79	2.27	1.70	2.72	1.16	5.67	10.14	2.67	3.00	5.10	3.31
July	....	....	15.52	....	....	3.87	4.05	1.41	5.64	7.05	13.92	5.42	6.65	5.79	5.96	4.71	4.70	8.06	8.10	5.99	2.26
Aug.	....	....	5.85	....	....	3.60	7.32	1.93	2.66	2.08	5.49	4.91	3.40	2.69	10.10	3.87	6.87	10.45	7.80	3.54	2.92
Sept.	....	....	13.13	....	....	2.24	2.80	9.42	0.79	5.72	2.81	2.87	8.87	8.93	3.47	5.66	4.38	7.02	8.49	2.82	7.44
Oct.	....	....	4.11	....	....	1.09	5.02	5.50	4.72	2.16	1.15	5.77	2.91	5.25	1.70	7.24	8.37	5.05	2.64	4.72	4.30
Nov.	....	....	11.13	....	2.62	8.25	3.75	3.38	8.27	2.96	5.07	6.93	3.27	3.80	2.17	1.50	1.22	2.30	2.60	1.26	6.00
Dec.	....	....	2.47	....	4.34	1.55	3.21	4.64	2.62	1.44	5.23	4.50	2.77	2.22	7.39	7.60	4.14	3.22	3.80	4.16	4.45
Total	....	....	82.31	....	....	49.00	51.91	50.59	39.45	47.91	55.67	58.47	51.72	49.62	53.27	57.10	57.80	54.81	50.91	47.86	47.53

WATER CONTRACT.

Between the City of Plainfield and the Plainfield-Union Water Company.

This agreement made and executed in duplicate this second day of May, eighteen hundred and ninety-two, BETWEEN the "INHABITANTS OF THE CITY OF PLAINFIELD," a municipal corporation of the State of New Jersey, party of the first part, and "THE PLAINFIELD WATER COMPANY," a body politic and corporate under and by virtue of the laws of the State of New Jersey, party of the second part.

WITNESSETH, That the said parties hereto (which are hereinafter designated by the terms "City" and "Company," respectively), each in consideration of the sum of one dollar to it in hand paid by the other, and the mutual covenants and agreements herein contained, do hereby covenant and agree each with the other in manner following, that is to say:

Said company agrees to supply pure and wholesome water to said city and the inhabitants thereof on the terms, in the manner and at the prices hereinafter stated, for the term of one year from the date hereof with the option to the city to renew said contract for the further term of one year and the further option to the city at any time during the two years following the date hereof to renew said contract for the period ending ten years from the date hereof on the same terms.

(1) The number of hydrants shall be 201, including the 45 hydrants already erected by the company; those not yet erected shall be located at the places shown on the map signed by the Mayor of said city and President of said company for identification. Two-way and four-way hydrants shall be located at the places indicated on said map respectively. Additional hydrants may be ordered by the city as hereinafter provided.

The hydrants not yet erected shall be similar to those already erected by the company; but the independent cut-off may be omitted.

(2) Whenever the laying of any pipes or mains by the company or the work connected therewith shall interfere with any road-bed, sewer, drain, pipe, conduit, street crossing, sidewalk, curb, gutter or other things, either public or private, or cause defects therein, the same shall be replaced and restored by the company without unnecessary delay, and left, as far as practicable, in as good condition as before such interference;

and where streets have been macadamized or spread with crushed stone, all repairs, to the depth to which such macadam of crushed stone extends, shall be made with crushed stone.

(3) All work shall be conducted in the most expeditious manner, and so as to obstruct the streets and highways for as short a time and as little as possible, and wherever settlements or defects shall appear along the line of any main or appurtenance, the same shall be forthwith repaired.

(4) When, in the pursuance of the public requirements, the Common Council shall direct and the city agree to pay for hydrants erected on any extension or extensions of the mains or pipes of the company then, upon the request of said Common Council, the company shall make the required extension or extensions to said mains or pipes and provide the necessary hydrants, valves and other appurtenances, provided, however, that the company shall not be required to make any such extension where the annual income along the same shall not amount to at least ten cents per lineal foot thereof.

(5) The company shall provide, set up and maintain an apparatus by means of which the height of the water in the standpipe shall be continuously and automatically indicated at the pumping station of the company, and such apparatus shall at all proper times be subject to examination by any person appointed for the purpose by the Mayor or Common Council of the city or any committee of said Council.

(6) The city may maintain at the pumping station of the company all such electrical apparatus as the city may deem necessary for the purpose of signalling alarms of fire, and the said city shall have the right to connect the same with the fire alarm system of the city. The company shall provide and maintain at the pumping station proper telephone connections with the public telephone exchange in operation in the city.

(7) The following are the terms and particulars of the tests to which the water works shall be subjected when it is desired by the Common Council of said city, or the committee on Fire and Buildings of said Council or by the Chief of the Fire Department, to show their efficiency in case of fire, viz.:

Five (5) streams shall be thrown, each one eighty (80) feet high to extreme drops, at one and the same time, each through fifty (50) feet of two and a half (2 1-2) inch hose, with one and one-eighth (1 1-8) inch straight conical nozzles, from any five hydrants on the mains of the company within that part of the city bounded by Richmond Street, Green Brook, Grant Avenue and Ninth Street, to be designated by said Council, or committee or chief. The company agrees that the works shall always be in readiness to comply with the fire test here-

inbefore described; and further, said company will always and immediately, upon alarm of fire being given, take whatever steps may be necessary to insure immediate use of the full power above stipulated for. But if more than four such tests shall be made in any one year the city shall pay for the water used in making such additional tests unless the water is not thrown as required thereby.

(8) The company shall at all times keep, and maintain the said water works, and all the machinery, appurtenances and apparatus connected therewith in first-class serviceable condition, and ready for instant use. All the hydrants shall be under the control of the officers of the fire department of the city on occasion of fire or alarm of fire, and the fire department shall be at liberty to use the same for reasonable practice or to inspect or test their efficiency. The hydrants shall be kept supplied with water and maintained in effective working order at all times.

(9) The company shall give the Chief of the Fire Department previous notice of any temporary stoppage or shutting off of the water, and where practicable, two (2) hours before such stoppage of water.

(10) The company shall, at or before the delivery of this contract, execute a bond to the city for the sum of ten thousand dollars, conditioned for the faithful performance by said company of all and singular the provisions of this contract on its part to be performed according to the true intent and meaning thereof.

(11) In case any hydrants shall remain out of order or fail to supply water for ten days, after written notice from the Mayor, Common Council, or the Fire Department of the city has been delivered to the company, then the city shall be entitled to deduct from the rental of said hydrant the sum of one dollar per day from the date of delivery of said notice, as long as the hydrant is not in good working order, provided, however, that the amount so deducted shall not exceed annual rental thereof. No other remedies, for any breach of this contract, are to be deemed barred by this paragraph.

(12) If a sewer system shall be constructed in said city during the term of this contract, or during the time over which this contract shall be extended, said company hereby agrees to furnish water for properly flushing such sewers, whether such sewers are or shall be owned by said city or not at the rate of ten cents per thousand gallons; or at the rate of four dollars per year per hydrant subject to use by said city for extinguishing fires therein, or for the sum of fifty dollars per mile of such sewers per year, as said city may prefer. Water for said purposes

to be furnished during the term of this contract and any extension of the same.

(13) The annual rental of hydrants for fire purposes shall be fifteen dollars each. The annual rental of each hydrant placed on subsequent extensions shall be fifteen dollars each. Water shall be supplied to the residents of the city, and to other consumers at annual rates not exceeding those in the following schedule:

Dwelling Houses.

For one faucet, $6.00. For each additional faucet, $2.00. For one water closet (pan or tank), $5.00. For each additional closet (pan or tank), $2.00. For one bathtub, $4.00. For each additional bathtub, $2.00. For one set wash tubs, not exceeding three, $3.00. For each additional set of tubs, $2.00.

Where two faucets are used, one for hot and one for cold water, both emptying into one vessel, but one charge will be made for both.

Where dwellings are occupied by more than one family, each family will be charged at above rates.

In cases where closets, tubs, faucets, or other fixtures supplied with water, are used by more than one family, extra charges will be made.

Stables.

Hotel, livery, omnibus and boarding stables, having not more than five stalls, $10.00. For each additional stall, $2.00. For each carriage or other vehicle, $1.00. Private stable, not exceeding two horses, $6.00. For each additional horse, $2.00. For one carriage, $2.00. For each additional carriage, $1.00. For one cow, $2.00. For each additional cow, $1.00.

Additional fixtures will be supplied at similar rates, and water for other purposes, at special rates.

Hydrants, according to needs, $6.00 to $15.00. Street washers on sidewalks, $5.00. Street washer for corner property, $7.00. A hose bibb, when hose is used, is charged as street washer. Drug stores, $10.00. Barber shops, stores and offices, $6.00 and upwards. Butcher shops, $8.00 and upwards. Building purposes: Brick, per thousand, 10 cents. Lime or cement, extra per barrel, 10 cents.

The company may in any case require the use of a meter, and charge a rate of not more than twenty-five cents per thousand gallons of water supplied through meters.

The charge for tapping shall be ten dollars, which shall include a service pipe from the main to the curb line.

In case meters are used, the annual minimum rates shall

be as follows: For 5-8 inch meter, $10.00. For 3-4 inch meter, $12.00, and for 1 inch meter, $25.00.

No meter of smaller size than the service pipe on which it is placed shall in any case be used. All meters shall be of a standard pattern, shall be the property of the company and maintained by the company in a serviceable condition.

The provisions of this contract respecting rates to be charged residents and other consumers in said city, are hereby agreed to be of the essence of this contract and any willful and continued violation of any of such provisions shall entitle said city at its option, in addition to any other remedies open to it, to rescind this contract or any renewal or extension thereof.

And said city agrees to pay to said company the sum of fifteen dollars per annum, for each hydrant, not less than 201 in number, it shall supply with water according to this contract, beginning on the date thereof as to the hydrants already erected and ready for use, and as to the others when the water is furnished to said other hydrants respectively, and notice to that effect is given by the company to the city, provided that at least ten hydrants shall be included in every notice and provided further that the company shall erect and supply said other hydrants with water at the earliest practicable date. Payment of such hydrant rental is to be made quarter yearly, on the first days of January, April, July and October in each year.

And it is hereby further agreed by and between the parties hereto as part of the consideration of this contract, and as a condition required by the said city for making the same, and agreeing to rescind a certain contract made by and between the said city and the Water Works Company of Plainfield, dated December 27, 1889, that the said company shall release any claim it may have or obtain against the said city to the sum of six thousand dollars or any part thereof heretofore paid to the said city by or on behalf of said Water Works Company in pursuance of said contract and shall indemnify and save harmless the said city against any and all claims to said sum of six thousand dollars, or any part thereof, and against all other claims arising out of said contract of December 27, 1889, that may be made by any person or persons or corporation, and in case of breach of said condition, the city shall have the option to cancel this contract or to take proceedings for specific performance, or otherwise as they may be advised.

IN WITNESS WHEREOF said party of the first part has caused these presents to be impressed with its corporate seal and signed by its Mayor, and attested by its City Clerk, and said party of the second part has caused these presents to be impressed with its corporate seal and signed by its President and

attested by its Secretary, by authority of its Board of Directors, the day and year first above written.

"INHABITANTS OF THE CITY OF PLAINFIELD"
(Seal) By A. GILBERT,
Mayor.

Attest:
F. W. RUNYON,
City Clerk.

"THE PLAINFIELD WATER SUPPLY COMPANY"
(Seal) By FRANK BERGEN,
President.

Attest:
E. R. POPE,
Secretary.

APPENDIX C

WATER ANALYSES

1.—**North Branch of Raritan at Ralston.**

2.—**North Branch of Raritan at North Branch.**

3.—**Lamington River below Hacklebarney.**

4.—**Passaic River at Berkeley Heights.**

5.—**Normahiggan Brook.**

6.—**Rahway River at Cranford.**

7.—**Water Supplied to Plainfield.**

8.—**Water from Plainfield Street Mains.**

9.—**Spicer Manufacturing Company's Well, Plainfield.**

10.—**Spicer Manufacturing Company's Well, Plainfield.**

11.—**Spicer Manufacturing Company's Well, Plainfield.**

12.—**Spicer Manufacturing Company's Well, South Plainfield.**

13.—**Aeolian Company's Well, Garwood.**

NOTE: The following analyses, unless otherwise noted, were made at the Laboratory of Hazen and Whipple, New York.

APPENDIX C.

Analyses of Waters.

1. WATER OF NORTH BRANCH OF RARITAN RIVER,
Collected at Ralston, September 16th, 1910,
at 12.30 p.m.

Turbidity	1
Color	13
Odor, very faintly vegetable.	
Nitrogen as albuminoid ammonia	0.062
Nitrogen as free ammonia	0.034
Nitrogen as nitrites	0.002
Nitrogen as nitrates	0.10
Iron	1.2
Total hardness	37.5
Alkalinity	43.0
Incrustants	0.0
Chlorine	2.0
Free Carbonic acid	2.0
Total bacteria per c. c.	650
B. Coli in 0.1 c. c. negative.	
In 1.0 c. c. positive. (presumptive).	
In 10.0 c. c. positive (presumptive).	
Microscopic organisms per c. c.	5
(No important organisms)	
Amorphous matter per c. c.	50

2. WATER OF NORTH BRANCH OF RARITAN RIVER,
Collected at North Branch Station, September 20th, 1910,
at 11.20 a. m.

Turbidity	18
Color	15
Odor, very faintly vegetable.	
Nitrogen as albuminoid ammonia	.096
Nitrogen as free ammonia	.024
Nitrogen as nitrites	.003
Nitrogen as nitrates	0.35
Iron	1.3
Total hardness	47.0
Alkalinity	56.0
Incrustants	0.0
Chlorine	4.0
Free carbonic acid	2.0
Total bacteria per c. c.	1200
B. Coli in 0.1 c. c. negative.	
In 1.0 c. c. positive.	
In 10.0 c. c positive.	
Microscopic organisms per c. c.	20
(No important organisms)	
Amorphous matter per c. c.	100

3. **WATER OF LAMINGTON RIVER,**

Collected One Mile Below Hacklebarney, September 16th, 1910, at 1.30 p. m.

Turbidity	1
Color	17
Odor, very faintly vegetable.	
Nitrogen as albuminoid ammonia	0.058
Nitrogen as free ammonia	0.014
Nitrogen as nitrites	0.003
Nitrogen as nitrates	0.400
Iron	0.20
Total hardness	50.0
Alkalinity	40.5
Incrustants	9.5
Chlorine	4.0
Free carbonic acid	2.0
Total bacteria per c. c.	300
B. Coli in 0.1 c. c. negative.	
In 1.0 c. c negative.	
In 10.0 c. c. positive.	
Microscopic organisms per c. c.	10
(No important organisms)	
Amorphous matter per c. c.	65

4. **WATER OF PASSAIC RIVER,**

Collected at Berkeley Heights Station.

Chemical Samples Collected October 3rd and Bacteriological Samples Collected September 23rd, 1910.

Turbidity	17
Color	37
Odor, distinctly vegetable—faintly earthy.	
Nitrogen as albuminoid ammonia	.128
Nitrogen as free ammonia	.024
Nitrogen as nitrites	.001
Nitrogen as nitrates	0.10
Iron	3.8
Total hardness	59.0
Alkalinity	57.0
Incrustants	2.0
Chlorine	5.5
Free carbonic acid	4.0
Total bacteria per c. c.	900
B. Coli in 0.1 c. c. negative.	
In 1.0 c. c. negative.	
In 10.0 c. c. positive.	
*Microscopic organisms per c. c.	158
Amorphous matter per c. c	175

*Anthophysa.

5. **WATER FROM NORMAHIGGAN BROOK,**
Collected September 23, 1910,
at 4.30 p. m.

Turbidity	5
Color	12
Odor, very faintly vegetable.	
Nitrogen as albuminoid ammonia	.100
Nitrogen as free ammonia	.044
Nitrogen as nitrites	.008
Nitrogen as nitrates	0.10
Iron	0.8
Total hardness	65.0
Alkalinity	62.0
Incrustants	3.0
Chlorine	6.0
Free carbonic acid	5.0
Total bacteria per c. c.	470
B. Coli in 0.1 c. c. negative.	
In 1.0 c. c. negative.	
In 10.0 c. c. positive.	
Microscopic organisms per c. c.	10
(No microscopic organisms)	
Amorphous matter per c. c.	60

6. **WATER OF RAHWAY RIVER,**
Collected at Cranford, N. J., September 23rd, 1910,
at 3.10 p. m.

Turbidity	6
Color	13
Odor, very faintly vegetable.	
Nitrogen as albuminoid ammonia	.032
Nitrogen as free ammonia	.040
Nitrogen as nitrites	.006
Nitrogen as nitrates	0.20
Iron	0.4
Total hardness	80.0
Alkalinity	73.0
Incrustants	7.0
Chlorine	8.5
Free carbonic acid	2.5
Total bacteria per c. c.	1200
B. Coli in 0.1 c. c. negative.	
In 1.0 c. c. negative.	
In 10.0 c. c. positive.	
Microscopic organisms	15
(No important organisms)	
Amorphous matter per c. c.	75

7. WATER FROM NETHERWOOD PUMPING STATION,
Collected in Plainfield, September 20th, 1910,
at 2:10 P. M.

Turbidity	0
Color	0
Odor	0
Nitrogen as albuminoid ammonia	.006
Nitrogen as free ammonia	.004
Nitrogen as nitrites	.000
Nitrogen as nitrates	1.20
Iron	0.0
Total hardness	126.0
Alkalinity	103.0
Incrustants	13.0
Chlorine	6.5
Free carbonic acid	5.0
Total bacteria per c. c.	37
B. Coli in 0.1 c. c. negative.	
In 1.0 c. c. negative.	
In 10.0 c. c. negative.	
Microscopic organisms per c. c.	0
(No important organisms)	
Amorphous matter per c. c.	0

8. WATER FROM NETHERWOOD PUMPING STATION,
Plainfield, N. J., May 17, 1910.
The L. M. Booth Co.

Parts per 1,000,000

ACIDS AND BASES

Sodium Oxide	07.9
Calcium Oxide	56.8
Magnesium Oxide	04.7
Iron Oxide / Alumina	01.0
Silica	16.2
Sulphuric Acid	12.0
Chlorine	06.4
Nitric Acid	01.9
Hydrogen Sulphide	none

HARDNESS, ETC.

Hardness	102.0
Causticity	none
Alkalinity	100.0
Metacidity	05.0
Acidity	none
Odor	none

Appearance clear and colorless.

Grains Per U. S. Gallon.

PROBABLE COMBINATION IN THE WATER.

Calcium Carbonate	5.83
Calcium Sulphate	0.11
Calcium Chloride	none
Calcium Nitrate	none
Magnesium Carbonate	none
Magnesium Sulphate	0.81
Magnesium Chloride	none
Magnesium Nitrate	none
Iron Carbonate	none
Iron Sulphate	none
Aluminum Sulphate	none
Iron Oxide / Alumina	0.05
Silica	0.94
Suspended Matter	none
INCRUSTING SOLIDS	7.74
Sulphuric Acid	none
Sodium Carbonate	none
Sodium Sulphate	0.16
Sodium Chloride	0.61
Sodium Nitrate	0.17
NON-INCRUSTING SOLIDS	0.94
Free Carbon Dioxide	0.25
Half Bound Carbon Dioxide	2.57
Hydrogen Sulphide	none
VOLATILE MATTER	2.82

9. WATER FROM DEEP WELL OF SPICER MANUFACTURING COMPANY IN PLAINFIELD, N. J.

Collected September 30th, 1910, at 2:35 P. M.

Turbidity	0
Color	0
Odor	0
Nitrogen as albuminoid ammonia	.002
Nitrogen as free ammonia	.004
Nitrogen as nitrites	.000
Nitrogen as nitrates	3.00
Iron	0.0
Total hardness	72.0
Alkalinity	62.0
Incrustants	10.0
Chlorine	12.5
Free carbonic acid	3.0
Total bacteria per c. c.	18
B. Coli in 0.1 c. c. negative.	
In 1.0 c. c. negative.	
In 10.0 c. c. negative.	
Microscopic organisms per c.c.	0
(No important organisms)	
Amorphous matter per c.c.	10

10. WATER FROM DEEP WELL OF SPICER MANUFACTURING COMPANY IN PLAINFIELD, N. J.,

Collected October 11th, 1910.

Sample No. 1.

Total hardness	78
Alkalinity	63

11. Sample No. 2.

Total hardness	78
Alkalinity	62

12. WATER FROM NEW WELL OF SPICER MANUFACTURING COMPANY AT NEW PLANT AT SOUTH PLAINFIELD,

Collected October 5th, 1910, at 1:20 P. M.

Turbidity	0
Color	0
Odor	0
Nitrogen as albuminoid ammonia	0.22
Nitrogen as free ammonia	.006
Nitrogen as nitrites	.000
Nitrogen as nitrates	0.50
Iron	0.05
Total hardness	198.0
Alkalinity	136.0
Incrustants	62.0
Chlorine	7.0
Free carbonic acid	6.0
Total bacteria per c. c.	520
B. Coli in 0.1 c. c. negative.	
In 1.0 c. c. negative.	
In 10.0 c. c negative.	
Microscopic organisms per c. c.	0
Amorphous matter per c. c.	0

13. WATER FROM DEEP WELL OF AEOLIAN COMPANY, CRANFORD,

Collected October 5th, 1910, at 3:20 P. M.

Turbidity	0
Color	0
Odor	0
Nitrogen as albuminoid ammonia	.004
Nitrogen as free ammonia	.000
Nitrogen as nitrites	.000
Nitrogen as nitrates	1.40
Iron	0.05
Total hardness	164.0
Alkalinity	102.0
Incrustants	62.0
Chlorine	9.5
Free carbonic acid	4.0
Total bacteria per c. c.	180
B. Coli in 0.1 c. c. negative.	
In 1.0 c. c. negative.	
In 10.0 c. c. negative.	
Microscopic organisms per c. c.	0
Amorphous matter per c. c.	0

APPENDIX D

REDUCTION OF WATER POWERS BY DIVERSION OF STREAMS

TABLE 1.

LAMINGTON RIVER POWERS BELOW HACKLEBARNEY.

TABLE 2.

LAMINGTON RIVER POWERS AT VLEITTOWN.

TABLE 3.

LAMINGTON RIVER POWERS AT BURNT MILLS.

TABLE 4.

RARITAN RIVER POWERS AT RARITAN.

TABLE 5.

RARITAN RIVER POWERS AT NEW BRUNSWICK.

APPENDIX D.

Reduction in Water Powers by Diversion of 8,000.000 Gallons, Daily, of Water from Various Streams

TABLE I.

Aggregate Reduction in power of all the water powers on the Lamington River from Pottersville to the proposed reservoir below Hacklebarney, based on continuous use of power 24 hours per day.

Total watershed, 33 square miles. It is proposed to take from the river above these powers the entire flow from 26.85 square miles of this watershed during times when the natural flow of the river at the proposed dam shall be less than 8,000,000 gallons per day, and 8,000,000 gallons daily whenever the natural stream flow at the dam will exceed 8,000,000 gallons daily, the excess flow to go down the river to the water powers below.

Month.	Average natural flow cubic feet per second per square mile.	Total flow cubic feet per second before diversion of 8,000,000 gallons daily.	Flow after diversion of flow from 26.85 square miles, or 8,000,000 gallons daily.	24-hour power before diversion. Total utilized head 62 feet.	24-hour power after diversion. Total utilized head 62 feet.	Reduction of 24-hour power. Total utilized head 62 feet.
Driest	.36	11.88	2.21	67	12	55
2nd	.43	14.19	2.64	80	15	65
3rd	.58	19.14	6.76	108	38	70
4th	.75	25.00	12.62	141	71	70
5th	.94	31.02	18.64	175	105	70
6th	1.23	40.00	27.62	221	156	65
7th	1.50	50.00	37.62	221	210	11
8th	1.82	60.00	47.62	221	221	0

Average reduction of power, based on 24-hours' use per day—58 H. P. for 7 months.

TABLE II.

Average Reduction in Power of the Water Powers on the Lamington River at Vleittown, N. J. Based on continuous use of power, 24 hours per day.

Month.	Total natural flow from 45.9 square miles before diversion of 8,000,000 gallons daily.	Flow after diversion of flow from 26.85 square miles, or 8,000,000 gallons daily.	24-hour power before diversion. Total utilized head 22 feet.	24-hour power after diversion. Total utilized head 22 feet.	Reduction of 24-hour power.
	Cu. ft. per second.	Cu. ft. per second.	Horse Power.	Horse Power.	Horse Power.
Driest	17.5	6.8	35	14	21
2nd	21.0	8.2	42	16	26
3rd	28.0	11.0	56	22	34
4th	37.0	25.0	74	50	24
5th	45.0	33.0	90	66	24
6th	59.0	47.0	90	90	..
Estimated average reduction in power, based on 24-hour day—26 H. P.					

TABLE III.

Average Reduction in Power of the Water Powers on the Lamington River at Burnt Mills. Based on continuous use of power, 24 hours per day.

Month.	Total natural flow from 91.8 square miles, before diversion of 8,000,000 gallons daily.	Flow after diversion of flow from 26.85 square miles, or 8,000,000 gallons daily.	24-hour power before diversion. Total utilized head, 5 feet.	24-hour power after diversion. Total utilized head, 5 feet.	Reduction of 24-hour power.
	cu. ft. per second.	cu. ft. per second.	Horse Power.	Horse Power.	Horse Power.
Driest	33	24	15	11	4
2nd	39	28	18	13	5
3rd	52	39	23	18	5
4th	69	57	31	26	5
5th	81	69	37	32	5
6th	110	98	37	37	0
Estimated average reduction in power, based on 24 hour day—5 H. P.					

TABLE IV.

Average Reduction in Power of the Water Powers on the Raritan River near Raritan, N. J.
Based on continuous use of power, 24 hours per day.

Month.	Total natural flow from 468 square miles, before diversion of 8,000,000 gallons daily.	Flow after diversion of flow from 26.85 square miles, or 8,000,000 gallons daily.	24-hour power before diversion. Total utilized head 15 feet.	24-hour power after diversion. Total utilized head 15 feet.	Reduction of 24-hour power.
	cu. ft. per second.	cu. ft. per second.	Horse Power.	Horse Power.	Horse Power.
Driest	168	156	245	230	15
2nd	202	190	294	277	17
3rd	270	258	395	378	17
4th	350	338	510	492	18
Estimated average reduction in power, based on 24-hour day—17 H. P.					

TABLE V.

Average Reduction in Power of the Power on the Raritan River at New Brunswick, N. J.
Based on continuous use of power, 24 hours per day.

Month.	Total natural flow from 895 square miles, before diversion of 8,000,000 gallons daily.	Flow after diversion of flow from 26.85 square miles, or 8,000,000 gallons daily.	24-hour power before diversion. Total utilized head 12 feet.	24-hour power after diversion. Total utilized head 12 feet.	Reduction of 24-hour power.
	cu. ft. per second.	cu. ft. per second.	Horse Power	Horse Power	Horse Power
Driest	320	307	348	334	14
2nd	382	369	416	402	14
3rd	520	507	566	552	14
4th	680	667	741	727	14
Estimated average reduction in power, based on 24-hour day—14 H. P.					

APPENDIX E

ESTIMATES OF COST OF CONSTRUCTION AND OPERATION

PLAN A.

GRAVITY SUPPLY FROM LAMINGTON RIVER.

PLAN B.

GRAVITY SUPPLY FROM RARITAN RIVER.

PLAN C.

PUMPED SUPPLY FROM NORTH BRANCH.

PLAN D.

PUMPED SUPPLY FROM PASSAIC AT BERKELEY HEIGHTS.

PLAN E.

GROUND WATER SUPPLY.

PLAN F.

SOFTENED GROUND WATER SUPPLY.

PLAN G.

EXTENSION OF PRESENT SUPPLY.

PLAN A. (See Part IV.)

GRAVITY WATER SUPPLY FOR PLAINFIELD FROM LAMINGTON RIVER.

Water to be collected in a large storage reservoir to be formed by building a masonry dam across the Lamington River below Hacklebarney, and to be conveyed to Plainfield, in a 24-inch pipe line, where it is to be filtered, stored in a covered filtered water reservoir and distributed in Plainfield either in new street mains, or in the present mains of the Plainfield-Union Water Company if acquired by condemnation or purchase.

Estimated Cost of Construction.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
	Costs.	Costs.
Hacklebarney Reservoir......	$ 180,000.00	$ 296,000.00
Conduit line..................	358,000.00	358,000.00
Filter plant..................	29,000.00	57,000.00
Distribution Reservoir........	70,000.00	139,000.00
Pipes to Plainfield............	52,000.00	52,000.00
Telephone line................	6,000.00	6,000.00
Mains in Plainfield............	286,000.00	286,000.00
Water power damages........	180,000.00	180,000.00
Totals	$1,161,000.00	$1,374,000.00

Annual Cost of Operation and Maintenance.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
Interest	$58,050.00	$68,700.00
Depreciation	4,550.00	5,600.00
Purification	3,000.00	3,300.00
Administration expenses	4,000.00	5,000.00
Distribution	5,000.00	6,000.00
Reservoirs	2,400.00	2,400.00
Pipe Lines...................	3,000.00	3,000.00
	$80,000.00	$94,000.00
Cost per 1,000,000 gallons.....	$55.00	$32.00

PLAN B. (See Part V.)

GRAVITY WATER SUPPLY FROM NORTH BRANCH OF RARITAN RIVER AT RALSTON.

Water to be collected in a large storage reservoir, to be formed by building a masonry dam across the North branch of the Raritan River about one and three-quarter miles below Ralston, and conveyed to Plainfield in a 30-inch pipe line, where it is to be filtered, stored in a covered filtered water reservoir and distributed to Plainfield, either in new street mains or in the present mains of the Plainfield-Union Water Company, if acquired by condemnation proceedings.

Estimated Cost of Construction.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
	Costs.	Costs.
Ralston Reservoir............	$ 356,000.00	$ 456,000.00
Conduit line..................	443,000.00	443,000.00
Filter plant..................	37,000.00	74,000.00
Distributing Reservoir.......	70,000.00	139,000.00
Pipes to Plainfield...........	52,000.00	52,000.00
Telephone line...............	6,000.00	6,000.00
Mains in Plainfield...........	286,000.00	286,000.00
Water power damages........	75,000.00	75,000.00
Totals	$1,325,000.00	$1,531,000.00

Annual Cost of Operation and Maintenance.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
Interest	$66,250.00	$ 76,550.00
Depreciation	5,350.00	6,050.00
Purification	5,000.00	7,000.00
Administration	4,000.00	5,000.00
Distributing system...........	5,000.00	6,000.00
Care of Reservoirs...........	2,400.00	2,400.00
Care of pipe lines............	3,000.00	3,000.00
Totals	$91,000.00	$106,000.00
Cost per 1,000,000 gallons....	$62.00	$36.00

PLAN C. (See Part VII.)

PUMPED SUPPLY OF WATER FOR PLAINFIELD FROM NORTH BRANCH OF RARITAN RIVER AT NORTH BRANCH STATION

The water is to be taken from the Raritan River, lifted, by centrifugal pumps to a settling and coagulating basin, filtered, pumped to a covered distributing reservoir near Plainfield and distributed in Plainfield either in new street mains or in the present mains of the Plainfield-Union Water Company, if acquired by purchase or condemnation.

Estimated Cost of Construction.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
	Costs.	Costs.
Intake	$ 7,000.00	$ 7,000.00
Pumping station	150,000.00	203,000.00
Purification works	52,000.00	98,000.00
Force main to Plainfield	374,000.00	374,000.00
Distributing Reservoir	70,000.00	139,000.00
Pipes to Plainfield	52,000.00	52,000.00
Telephone line	3,000.00	3,000.00
Mains in Plainfield	286,000.00	286,000.00
Diversion of water	15,000.00	15,000.00
Total Cost of construction..	$1,009,000.00	$1,177,000.00

Annual Cost of Operation and Maintenance.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
Interest	$50,450.00	$ 58,850.00
Depreciation	7,550.00	9,650.00
Pumping	16,000.00	37,700.00
Purification	7,000.00	14,800.00
Administration expenses	4,000.00	4,000.00
Care of distribution system	5,000.00	6,000.00
Care of pipe lines	3,000.00	3,000.00
Total annual cost	$93,000.00	$134,000.00
Cost per 1,000,000 gallons	$64.00	$46.00

PLAN D. (See Part VIII.)

PUMPED SUPPLY OF WATER FROM THE PASSAIC RIVER AT BERKELEY HEIGHTS, N. J.

The water is to be taken from the Passaic River, lifted by centrifugal pumps to a settling and coagulating basin, filtered, pumped to a covered distributing reservoir near Plainfield and distributed in Plainfield either in new street mains, or in the present mains of the Plainfield-Union Water Company, if acquired by purchase or condemnation.

Estimated Cost of Construction.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
	Costs.	Costs.
Intake	$ 7,000.00	$ 7,000.00
Pumping station	150,000.00	203,000.00
Purification works	52,000.00	98,000.00
Force mains	80,000.00	80,000.00
Tank on Mountain	6,000.00	6,000.00
Distribution reservoir, Plainfield	70,000.00	139,000.00
Telephone lines	2,000.00	2,000.00
Pipes to Plainfield	52,000.00	52,000.00
Street mains in Plainfield	286,000.00	286,000.00
Diversion of water	100,000.00	100,000.00
Total cost of construction	$805,000.00	$973,000.00

Annual Cost of Operation and Maintenance.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
Interest	$40,250.00	$ 48,650.00
Depreciation	5,350.00	7,500.00
Pumping	12,500.00	25,450.00
Purification	11,900.00	23,400.00
Administration	4,000.00	4,000.00
Care of distribution system	5,000.00	5,000.00
Care of pipe lines	2,000.00	2,000.00
Totals	$81,000.00	$116,000.00
Cost per 1,000,000 gallons	$55.00	$40.00

PLAN E. (See Part IX.)

NEW GROUND WATER SUPPLY TO BE SECURED IN THE NEIGHBORHOOD OF PLAINFIELD.

(Not softened)

Water to be secured from deep wells sunk in the red shale formation in the neighborhood of Plainfield, the precise location for the plant to be determined by test wells. It is assumed in this estimate that the water will be soft enough for use without treatment and that it will be pumped to a distributing reservoir near Plainfield and distributed in Plainfield either in new street mains or in the present mains of the Plainfield-Union Water Company, if acquired by purchase or condemnation.

Estimated Cost of Construction.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
	Costs.	Costs.
Railroad facilities	$ 20,000.00	$ 20,000.00
Well plant, including land	103,000.00	149,000.00
Force mains	40,000.00	52,000.00
Reservoir	71,000.00	139,000.00
Connection to distribution mains in Plainfield	52,000.00	52,000.00
Pumping stations	141,000.00	263,000.00
Telephone line	1,000.00	1,000.00
Street mains in Plainfield	286,000.00	286,000.00
Totals	$714,000.00	$962,000.00

Annual Cost of Operation and Maintenance.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
Interest	$35,700.00	$ 48,100.00
Depreciation	5,400.00	9,500.00
Pumping	14,900.00	30,400.00
Administration	4,000.00	4,000.00
Care of distribution system	5,000.00	5,000.00
Care of pipes and wells	2,000.00	3,000.00
Totals	$67,000.00	$100,000.00
Cost per 1,000,000 gallons	$45.00	$34.00

PLAN F. (See Part IX.)

NEW GROUND WATER SUPPLY TO BE SECURED IN THE NEIGHBORHOOD OF PLAINFIELD.

(Water to be Softened)

This supply is the same as in Plan E, except in the event of softening being required, in which case the character of the water is assumed to be the same as that at Aeolian Company's well at Garwood. Water to be pumped to softening plant at Washingtonville Reservoir, softened, and distributed in new street mains or in the present mains of the Plainfield-Union Water Company if acquired by purchase or condemnation.

Estimated Cost of Construction.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
Railroad facilities	$ 20,000.00	$ 20,000.00
Well plant, including land	103,000.00	149,000.00
Force mains	121,000.00	121,000.00
Reservoir at Washingtonville	71,000.00	139,000.00
Purification works	46,000.00	82,000.00
Connection with Plainfield mains	52,000.00	52,000.00
Power house, etc.	141,000.00	263,000.00
Telephone line	1,000.00	1,000.00
Street mains in Plainfield	286,000.00	286,000.00
Totals	$841,000.00	$1,113,000.00

Annual Cost of Operation and Maintenance.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
Interest	$ 42,050.00	$ 55,650.00
Depreciation	6,450.00	10,750.00
Pumping	14,500.00	30,600.00
Purification	13,000.00	24,000.00
Administration	4,000.00	4,000.00
Care of distribution system	5,000.00	5,000.00
Care of pipes and wells	2,000.00	3,000.00
Totals	$87,000.00	$133,000.00
Cost per 1,000,000 gallons	$59.00	$45.00

(See Part IX.)

Provisional Estimate, for Purposes of Comparison Only, of Cost of Adopting Present Pumping Plant at Netherwood to Conform to the Same Standards as the Proposed New Supplies for Plainfield as to Quality and Quantity.

The plan contemplates laying a new force main from the present plant to a softening plant and distributing reservoir near Plainfield, and conducting this softened water to Plainfield for distribution in the present street mains. Future increase in supply to be secured through deep wells with an efficient pumping plant similar to that described for the proposed new deep well plant, all the water to be softened.

Estimated Cost of Construction.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
	Costs.	Costs.
Present wells, pumping station and land	$161,000.00	$161,000.00
Force mains to reservoir	115,000.00	115,000.00
Changes at present plant	6,000.00	6,000.00
No reservoir at Washingtonville	70,000.00	139,000.00
Purification works	46,000.00	82,000.00
Connection with Plainfield mains	52,000.00	52,000.00
Telephone lines	1,000.00	1,000.00
Street mains in Plainfield	286,000.00	286,000.00
New pumping and well plant	....	190,000.00
Totals	$737,000.00	$1,032,000.00

Annual Cost of Operation and Maintenance.

Items.	Capacity 4,000,000 gallons daily.	Capacity 8,000,000 gallons daily.
Interest	$36,850.00	$ 51,600.00
Depreciation	7,050.00	11,500.00
Pumping	18,500.00	32,900.00
Purification	13,000.00	24,000.00
Administration	4,000.00	4,000.00
Care of distribution system	5,000.00	5,000.00
Care of pipe lines and wells	2,000.00	3,000.00
Totals	$86,400.00	$132,000.00
Cost per 1,000,000 gallons	$59.00	$45.00

***Note.**—In the foregoing estimate of the cost of adopting the present Netherwood pumping station to conform to the same standards as the proposed new plants, the amount included for the value of the "present pumping station and land" is for the physical plant only in addition to an allowance of $46,000.00 for land for extensions. No valuation is included for franchise rights, going-value, or property outside the Netherwood plant, either tangible or intangible. If these items were included the property values and annual charges would be greatly increased. This estimate is prepared only to show that even with all these large items excluded the cost of placing the Netherwood supply on the same basis as the other proposed new supplies would be substantially the same as to install a new plant in its entirety, allowing about $115,000.00 as the value of the existing original system of wells, the pumping station, stand pipe and land now appurtenant to the plant. In this valuation no account has been taken of the new wells, pump well and pumping engine now in process of installation.